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ABSTRACT

Much of the effort involved in a major restructuring of the Graduate Record Examinations (GRE) Aptitude Test was intended to result in the creation of an analytical module to supplement the verbal and quantitative sections of the test, thus providing broadened measurement. Factor extension analysis was used in the present study to investigate further the characteristics of seven experimental analytical item types that had been administered in the experimental section of two operational forms of the Aptitude Test. The extension analysis included: (1) examining the loadings of analytical items on the factors extracted from operational forms, (2) computing the contribution made by operational factors to explaining both the intercorrelations among experimental items and the variance of each experimental test, and (3) analyzing the relationships among analytical items that were not explained by operational form factors. The seven analytical item types were shown to be differentially related to the dimensions underlying the current Aptitude Test, in terms of both their independence of verbal and quantitative factors and their relationship to specific abilities. Furthermore, all but one of the seven experimental analytical tests appeared to have at least one interpretable dimension that was distinct from any found in the operational form of the Aptitude Test. (Author)

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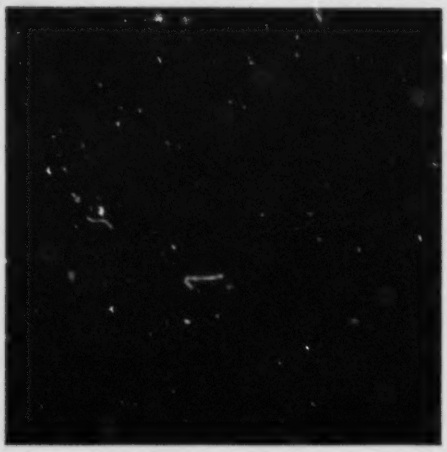

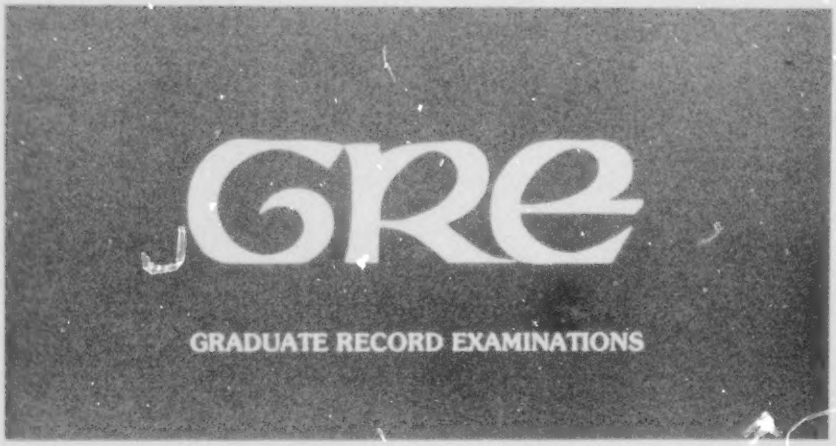

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A FACTOR ANALYTIC INVESTIGATION OF SEVEN EXPERIMENTAL ANALYTICAL ITEM TYPES

Donald E. Powers

with

Spencer Swinton
Dorothy Thayer
Allan Yates

GRE Board Professional Report GREB No. 77-1P

June 1978

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EDUCATIONAL TESTING SERVICE, PRINCETON, NJ

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Abstract

Much of the effort involved in a major restructuring of the Graduate Record Examinations (GRE) Aptitude Test has been the development, pretesting, and analysis of a number of experimental analytical item types. These activities were intended to result in the creation of an analytical module to supplement the verbal and quantitative sections of the test, thus providing broadened measurement.

Factor extension analysis was used in the present study to investigate further the characteristics of seven experimental analytical item types that had been administered in the experimental section of two operational forms of the Aptitude Test. The extension analysis included:

(1) examining the loadings of analytical items on the factors extracted from operational forms,

(2) computing the contribution made by operational factors to explaining both the intercorrelations among experimental items and the variance of each experimental test,

and (3) analyzing the relationships among analytical items that were not explained by operational form factors.

The seven analytical item types were shown to be differentially related to the dimensions underlying the current Aptitude Test, in terms of both their independence of verbal and quantitative factors and their relationship to specific abilities. Furthermore, all but one of the seven experimental analytical tests appeared to have at least one interpretable dimension that was distinct from any found in the operational form of the Aptitude Test.

INTRODUCTION

Background

During the past three years the GRE Board has supported a number of activities related to the restructuring of the GRE Aptitude Test (Altman et al., 1975). One of these activities has been the development, pretesting, and analysis of a number of experimental item types, most of which have been investigated with the intention of creating a new Aptitude Test measure designed to supplement the verbal and quantitative scores now reported, thus providing broadened measurement (Conrad, 1976). The items of interest in the study reported here were those abstract reasoning items that were included on an experimental basis in two GRE Aptitude Test administrations. A list of the item types and their administration dates is given in Table 1 below. As can be seen, five of the experimental tests were spiralled in the experimental section of an operational form given in December, 1975; the other two were spiralled with a form given in June, 1976. Two of the tests contained more than one item type. Examples of each analytical item type appear in Appendix A.

Table 1

Experimental Tests

Item Type	
Letter Sets	December 1975
Logical Reasoning/Letter Sets	December 1975
Letter Sets/Analytical Reasoning	December 1975
Evaluation of Evidence	December 1975
Analysis of Explanations	December 1975
Logical Diagrams	June 1976
Deductive Reasoning	June 1976

A number of analyses of these experimental item types had been completed prior to the research reported herein. These analyses addressed questions about the difficulty, reliability, speededness, and validity of the new item types. An additional determination that was sought in these previous analyses concerned the new items' independence of the current verbal and quantitative measures. Their independence was assessed by examining the correlations of each experimental test with V and Q scores and by determining examinees' reactions to the items, as expressed in their answers to the question "Do the questions in the last section seem to measure skills <u>different</u> from those tested in the verbal and quantitative portions of the GRE?" Table 2 shows that, for all but the logical reasoning test, an overwhelming majority of students judged the tests to be independent of V and Q. Furthermore, although there were differences among the tests with respect to their association with V and Q, the overall pattern of correlations suggested that the tests are somewhat less independent of V and Q than V and Q are of each other. That is, the typical correlation between V and Q,

which is reported to be .50 - .60, is somewhat lower on the average than the correlation of any of the analytical tests with either V or Q. It seems clear, then, that each of the experimental measures shares some common dimension(s) with either the verbal section or the quantitative section or both. On the other hand, however, no correlation was so high that the possibility of significant unique variance in each of the tests could be dismissed.

Table 2

Data on Independence of Experimental Item Types[a]

Experimental Item Type	Correlations with: V	Q	Skills measured different from V and Q? (% students answering "yes")
Letter Sets	.45 (.48)[b]	.60 (.62)	80%
Logical Reasoning	.69 (.90)	.42 (.68)	59
Analytical Reasoning	.63 (.78)	.64 (.78)	80
Evaluation of Evidence	.64 (.73)	.53 (.59)	84
Analysis of Explanations	.65 (.73)	.61 (.66)	81
Analysis of Relationships (Logical diagrams)	.59 (.67)	.68 (.77)	81
Deductive Reasoning	.41 (.52)	.62 (.79)	Not asked

[a]Correlations reported for Logical Reasoning and Analytical Reasoning are based on pretests administered in either 1971 and 1973, not on the pretests specified in Table 1. The 1971 and 1973 pretests contained a full complement of the respective items whereas, for the sake of obtaining intercorrelations of item types, two of the pretests specified in Table 1 included both Letter Sets (15 items) and only 15 of either Logical Reasoning or Analytical Reasoning.

[b]The correlation given in parentheses has been corrected for attenuation due to test unreliability.

Purpose

The major objective of the research reported here was to assess, from a factor analytic viewpoint, the relationships (both shared and unshared) between two currently used (unrestructured) forms of the GRE Aptitude Test and the seven abstract reasoning or analytical item types listed above. The accumulation of additional evidence related to these item types seemed especially valuable to the task of establishing the construct validity of the Aptitude Test's new analytical module, which will include several of these item types. The view held here is one consistent with the definitions found in the Standards for Educational and Psychological Tests (American Psychological Association, 1974)--that evidence of construct validity is found not in a single research study but in judgments based on an accumulation of results. The results of the research described in this report are intended to add to the accumulation of results concerning the items making up the new analytical module. Articulation of the validity of the item types has been addressed here from both the convergent and the discriminant modes as discussed by Campbell and Fiske (1959), who argued that the validity of a measure is determined as much by its independence of constructs to which it should not be related as by its correlation with those variables to which it should bear relationship.

In addition to providing further evidence of the construct validity of the new item types, a second result of the factor analytic methodology employed in this study was predicted to be additional basic information about the structure of the item types, particularly the more molecular dimensions having relevance for test development activities. It was hoped that this information would add to the understanding of each of these new item types.

A limitation of the study is that, since no group of examinees (except those taking Letter Sets, which was given in combination with two other types) received more than one of the seven analytical item types, the relationship among these item types, and specifically the three types earmarked for the new analytical section of the Aptitude Test, could not be determined. A factor analytic study based on the performance of a single group of examinees on several of the item types is necessary to make this determination.

Finally, a secondary objective was a replication of the results of a previous factor analytic study (Powers, Swinton, and Carlson, 1977). Such a replication was considered desirable, since (1) the Powers et al., (1977) findings are the first such factor analytic results reported for the GRE Aptitude Test, and (2) there were reported differences between the two forms investigated in that study with respect to several of the less prominent factors that were extracted. The present study was thought to be useful for assessing the extent to which these less prominent factors were specific to particular forms of the test.

PROCEDURES

As in the previously reported study (Powers et al., 1977), factor extension methodology (Dwyer, 1937; Harman, 1938) was the primary analytic procedure used. Minres solutions (Harman and Jones, 1966) were computed for each of the two operational forms given in either December, 1975 or June, 1976. Basic data used were the right and wrong responses to all 150 verbal and quantitative items in each test form. The interitem tetrachoric correlation matrices were analyzed and the resulting solutions were subjected to both orthogonal and oblique rotations, using Kaiser's (1958) varimax criterion and Jennrich and Sampson's (1966) direct oblimin (quartimin) criterion. Decisions regarding the number of factors retained in the final solutions were based on several considerations: the number of eigenvalues greater than one, the break in the magnitude of eigenvalues, and the proportion of common variance accounted for by various numbers of factors. Rotation of several numbers of factors was also used to select the most stable and interpretable solution for each of the two forms. Both the orthogonal and the oblique solutions were extended to each of the experimental tests associated with each of the two operational forms, resulting in estimates of the factor loadings of each new item on each of the factors extracted from the operational forms. Tucker (1971) has provided the technique for extending oblique factors. Next, the factors found in each operational form were statistically removed from the interitem correlation matrix of each experimental test by subtracting the product of the extension matrix and its transpose. This product is an estimate of the correlation matrix of experimental test items, based on only those dimensions of covariance shared with the operational form factors. This results in a matrix of residuals (independent of the rotation applied to the operational factors), whose examination allowed an assessment of the nature of any interitem relationships unexplained by the verbal and quantitative factors found in the operational forms. Each of the seven residual matrices resulting from the extension analyses of the seven experimental tests was subsequently factor analyzed using the same methods described above to discover any dimensions common to the items in each experimental test but unexplained in terms of the verbal and quantitative factors underlying the items in the operational forms.

Samples were drawn from each of two GRE Administrations. A random sample was drawn of approximately 7,000 candidates taking the operational form and one of the five experimental tests given in December, 1975. About 6,000 examinees taking the operational form and either of the two experimental tests given in June, 1976 constituted the second sample. The first sample was representative of all examinees taking the GRE Aptitude Test in December, 1975. The second, however, is not necessarily representative of all candidates taking the exam in June, 1976, since the two experimental forms given for this administration were shipped only to selected test centers, ones that were somewhat closer to ETS's Princeton, N.J., office than was the typical center.

All the factor analyses computed in the study were interpreted in the light of several sources of input: item analysis data pertaining to the difficulty and speededness of items, item classification schemes used by test developers, and the authors' own judgments of items, including impressions gained from a previous factor analysis.

RESULTS

Description of Operational Factors

An eight-factor varimax solution was retained for each of the operational forms. In general, there is a good deal of similarity between the solutions retained here and those reported in the previous study (Powers et al., 1977). Again, differences between the two forms were noted with respect to less prominent factors. As with the previously analyzed forms, however, three factors--two verbal and one quantitative--account for about three quarters of the common variance among items. These three major factors reflect a general quantitative ability, an ability to deal with connected discourse (reading comprehension), and a skill related to words in isolation (vocabulary). The remaining factors revealed aspects of the structure of the quantitative section of the test, the differential effect of specific types of reading passages and/or discrete verbal items, and the effects of the length of each separately timed section (speed). Table 3 gives a summary of the factors found in each form, ordered according to their contribution to the common variance of each test form. Detailed descriptions of the analysis of each form is given in Appendix B.

Table 3

Summary of Varimax Factors Found in Two Operational Forms

	Factor Name	
Factor	Form A	Form B
I	Reading comprehension: connected discourse	General quantitative
II	General quantitative	Reading comprehension: connected discourse
III	Words in isolation: vocabulary	Words in isolation: vocabulary
IV	Quantitative: easy algebra	Speed of response to discrete verbal items
V	Speed of response to discrete verbal items	Data interpretation: algebra
VI	Reading speed	Reading speed
VII	Data interpretation	Data interpretation: extraction and manipulation
VIII	Reading comprehension: specific content	Easy opposites

Description of Experimental Tests in Terms of Operational Factors (Varimax Solution)

Factor extension matrices, given in Tables C1-C7 in Appendix C, show the loadings of the items in each experimental test on the factors found in the operational form with which each was given. A description of each test in terms of the operational form factors is given below.

Experimental Test X_{21}--Letter Sets. The letter sets test appears to share two major dimensions with operational form A: Factor I, reading comprehension, and Factor II, general quantitative ability. Twenty-three of the first 28 items in the test load highest on the reading comprehension factor; thirteen (of the last 16 items) load highest on the general quantitative factor and five on Factor IV, easy algebra. Though it may seem unusual initially that reading comprehension is instrumental in dealing with letter set items, which bear little resemblance to typical reading comprehension items, effectively responding to such items apparently requires a skill to deal with the "connectedness" of groups of letters that is similar to the ability to deal effectively with the type of connected discourse in sentence completion and reading comprehension items, item types defining Factor I.

The relatively large number of high loadings on Factor II suggests that general quantitative ability also plays a fairly important role in responding to items of this type. The ability to see relationships among letters may be analogous to dealing with relationships among symbols found in algebra items that were instrumental in defining the general quantitative factor.

The large number of highest loadings of final letter set items on Factor II suggests that the kind of speed associated with quantitative ability may be more important than general quantitative ability itself in answering letter set items. Factor IV, a quantitative factor characterized best by loadings from easy algebra items, has loadings greater than .20 from nearly all letter set items (greater than .30 for half of them), suggesting the contribution made by an ability to deal effectively with symbols.

Although none of the items load highest on any factor other than Factors I (reading comprehension), II (general quantitative), and IV (quantitative: easy algebra), there is a relatively high number of moderate loadings on Factors V and VI. Factors V and VI, speed factors associated with the verbal sections of the test, show a modest number of loadings greater than .20 and demonstrate the importance of working rapidly, apparently both in processing information and in responding to items in the letter sets test.

Experimental Test X_{22}--Logical Reasoning and Letter Sets. Test X_{22}, also given with form A, contains 15 logical reasoning items in the first half of the test and 15 letter set items as the final half. It is therefore necessary to discuss the items separately, with somewhat more emphasis on logical reasoning items, since letter set items have been discussed in connection with test X_{21}.

The logical reasoning item type requires the evaluation of reasoning contained in brief statements or passages. In some of the questions the answer choices are conceivable solutions to a posed problem. This type of question may require the examinee to think logically (recognize the point of an argument, perceive presuppositions essential to or supporting an argument or chain of reasoning, draw conclusions from given evidence or premises, infer missing material, or apply principles governing one argument to another) or critically (identify and/or evaluate methods of argument and persuasion, differentiate between statements of fact and opinion, analyze evidence and assess claims critically).

Nearly all (14 of 15) of the logical reasoning items have their highest loadings on Factor I. Thirteen loadings are greater than .20 and four are greater than .40. Factor II, general quantitative, is the next most influential factor with 9 loadings greater than .20 and a highest loading from one item. Factor III, vocabulary, has three loadings in the .20s. No other factor shows any notable loadings. The ability to deal with and comprehend connected discourse appears then to be the major dimension shared with the current operational test.

The letter sets items in this test are defined by loadings on the reading comprehension, general quantitative, and reading speed factors, confirming the importance of the abilities underlying test X_{21}. The relatively higher underlying influence of general quantitative ability in this test reflects the position of the items in this test.

Experimental Test X_{23}--Letter Sets and Analytical Reasoning. When letter sets items are placed in the first half of an experimental test, as they are in X_{23}, which was administered with form A, they show a slightly different pattern of loadings. Though they continue to load on reading comprehension (four of 15 items load highest on this factor), they show an even stronger tendency to load heavily on Factor IV, easy algebra. Both factors have a substantial number of significant loadings, however: 14 of 15 reading comprehension factor loadings are greater than .20; 12 of 15 Factor IV loadings are greater than .20, with seven greater than .30.

The analytical reasoning items, which occupy the final half of test X_{23}, have most (13) of their highest loadings on Factor II, general quantitative. The only other factor showing any substantial patterns of loadings is Factor I, reading comprehension. Both Factor I (reading comprehension) and Factor II (general quantitative) have a large number of high loadings. Nearly half of the loadings from Factor II, in fact, are greater than .40. A modest number of loadings greater than .20 are spread over the remaining factors.

Because of their position at the end of the test, it is difficult to get a good assessment of the dimensions this test shares with the operational form. At face value, the results suggest that general quantitative ability and/or speed linked to quantitative ability are important factors. The latter assessment, however, may be at least partially a function of the items' position in the test.

Experimental Test X_{24}--Evaluation of Evidence. The evaluation of evidence item type, given in the experimental section of form A, requires the examinee to read a passage describing a fact situation and a conclusion based on that situation. The examinee then responds to a series of statements by considering the relationship of each to the fact situation: whether it proves, supports, disproves, or weakens the conclusion, or whether it is irrelevant to it.

The overwhelming prepondence of items (34 of 40) load highest on Factor I, reading comprehension. Three of the remaining six load highest on speed of response, Factor V. Factor VI, reading speed, and Factor II, general quantitative, also have a moderate number of loadings greater than .20. In general, however, the ability to deal with connected discourse is the major component shared with the operational form. Since the situation descriptions in the test look considerably like reading comprehension passages, this finding is not unexpected.

Experimental Test X_{25}--Analysis of Explanations. The analysis of explanations test, also given with operational form A, is similar in some respect to the evaluation of evidence test in that both contain sets of questions associated with a fact situation. The analysis of explanation items, however, present a result (instead of a conclusion) for each situation. The examinee then considers each of a series of statements for which he chooses an answer according to whether the statement is inconsistent with, possibly explanatory of, deducible from, relevant or irrelevant to the stated fact situation, the result, or both.

A majority (27 of 40) of the items in this experimental test have their highest loadings on the reading comprehension factor. Nine others load highest on the general quantitative factor. These latter items tend to be at the end of the test, suggesting that the common dimension may be speed associated with quantitative ability. Interestingly, the final items at the end of this section do not load on either of the verbal speed factors, as some of the latter items in the other experimental tests do. In fact, only three loadings greater than .20 appear on all of the other six factors.

Experimental Test Y_1--Logical Diagrams. Nearly all (45 of 50) of the logical diagram items, given with form B, load higher on the general quantitative factor (Factor I from form B) than on any other. The remaining five items do not load consistently highest on any particular factor. Factor I has loadings greater than .40 for 20 of the items in the test and loadings greater than .20 for 44 of 50 items. Factor II, from form B, reading comprehension, has a substantial number of moderate loadings (six greater than .40, 40 greater than .20). Factor VI, reading speed, has six loadings greater than .20. It is clear then that general quantitative ability is the major dimension shared with the operational form.

Experimental Test Y_{10}--Deductive Reasoning. The second test given with form B, deductive reasoning, is one requiring extensive manipulation of symbols according to a formal logic system that is presented in the test. Examinees must consider the situations symbolized in each item and to determine which of four choices symbolizing various situations are either consistent with or inconsistent with the situations in the item stem.

By far the most important dimension shared by this test and the operational form with which it was administered is general quantitative ability. Seventeen of 20 items load higher on this factor than on any other and all of the loadings on this factor are greater than .20 (13 are greater than .30). The relative importance of quantitative ability is confirmed by virtue of two remaining items' having their highest loadings on Factor V, the data interpretation dimension associated with a set of data interpretation items involving algebraic manipulation according to a specified calculus. Six loadings greater than .20 appear on this factor. Positive loadings on this factor from items in the first half of the test, in contrast to slightly but consistently negative loadings near the end of the test suggest that the extensiveness of the manipulation required in the items may be an important dimension. Five loadings greater than .20 on Factor VI, reading speed, from items at the end of the test suggest that speed in dealing with connected discourse is slightly important to successful performance on this test, possibly because the examinee must not only learn a formal logic system but also at various points in the test he may need to review test directions.

Unexplained Relationships Among Items within Experimental Tests

After we computed the loading of the items in each experimental test on each of the factors found in the operational tests, the operational factors were statistically removed by subtracting the product of the extension matrix and its transpose. This product is an estimate of the intercorrelation matrix of the items in that experimental test, based on only those dimensions of item covariance that are shared with the operational test. The residual correlations and the difference between reproduced and estimated item communalities, i.e., the diagonal entries in the residual matrix, can be examined to determine the degree to which the experimental test reflects additional dimensions not shared with the operational test with which it was administered. Table 4 shows the residual correlations, both the diagonal and the off-diagonal entries, for each of the seven experimental tests.

Table 4

Distribution of Residuals (After Removal of Varimax Factors)

Experimental Tests X_{21} - X_{24}, Y_1 and Y_{10}

Test	Size	Diagonals		Off-diagonals	
		N	Cum. %	N	Cum. %
X_{21}	below .10	0	0.0	169	21.7
	.10 - .19	5	12.5	325	63.3
	.20 - .29	16	52.5	191	87.8
	.30 - .39	10	77.5	81	98.2
	.40 or above	9	100.0	14	100.0
	Total	40		780	
		LR	LR	LR	LR
X_{22}	below .10	8	53.3	88	83.8
	.10 - .19	4	80.0	15	98.1
	.20 - .29	3	100.0	2	100.0
	.30 - .39	0	100.0	0	100.0
	.40 or above	0	100.0	0	100.0
	Total	15		105	
		AR	AR	AR	AR
X_{23}	below .10	1	6.7	66	62.9
	.10 - .19	1	13.4	22	83.8
	.20 - .29	4	40.0	5	88.5
	.30 - .39	4	66.7	8	96.2
	.40 or above	5	100.0	4	100.0
	Total	15		105	

Table 4 (Cont.)

Test	Size	Diagonals		Off-diagonals	
		N	Cum. %	N	Cum. %
X_{24}	below .10	15	37.5	591	75.8
	.10 - .19	8	57.5	128	92.2
	.20 - .29	8	77.5	26	95.5
	.30 - .39	6	92.5	11	96.9
	.40 or above	3	100.0	14	100.0
	Total	40		780	
X_{25}	below .10	12	30.0	599	76.8
	.10 - .19	9	52.5	126	92.9
	.20 - .29	6	67.5	38	97.8
	.30 - .39	8	87.5	14	99.6
	.40 or above	5	100.0	3	100.0
	Total	40		780	
Y_1	below .10	9	18.0	637	52.0
	.10 - .19	14	46.0	440	87.9
	.20 - .29	8	62.0	108	96.7
	.30 - .39	10	82.0	34	99.5
	.40 or above	9	100.0	6	100.0
	Total	50		1225	
Y_{10}	below .10	3	15.0	124	65.3
	.10 - .19	10	65.0	53	93.2
	.20 - .29	6	95.0	12	99.5
	.30 - .39	1	100.0	1	100.0
	.40 or above	0	100.0	0	100.0
	Total	20		190	

As can be seen from Table 4, there are differences among the seven experimental tests with respect to how well they are explained in terms of the factors underlying the operational tests. The logical reasoning items in the first half of test X_{22} appear to be the best explained of any item type in terms of the operational factors. Fewer than half of the diagonal residuals associated with these items and only about 16% of the off-diagonal residuals are greater than .10.

The next best explained tests, in terms of small residuals, are the evaluation of evidence and analysis of explanation tests, which have comparable distributions of residuals. The analytical reasoning and deductive reasoning tests have distributions of residuals that are similar to each other, with somewhat higher residuals than the evaluation of evidence and analysis of explanation types. The logical diagram test is even less well explained than any of the preceding tests and letter sets appears to be the "most unique" test of any of those investigated here. The fact that a test is not well explained by extended operational factors does not in itself constitute proof that the unexplained residuals measure a useful trait, however.

To assess just <u>how</u> well these experimental tests are explained by the factors in the operational tests, one may refer to the results of the extension analyses conducted in conjunction with a previous factor analysis (Powers <u>et al.</u>, 1977). By contrast, the <u>least</u> well explained of eight experimental tests investigated in that study was a fairly speeded test containing scientific passages and associated reading comprehension items. Each of those tests, which were V and Q variants, contained from 3 to 15% of off-diagonal residuals greater than .10. Comparable figures for the tests investigated in the present study range from 16 to 78%. Thus the best explained test in the present study (logical reasoning) is slightly less well explained than the least well explained experimental test in the previous study.

It is clear then that the common factor structures found in the operational tests do not do a very good job of reproducing the interitem correlations, i.e., the correlations among items within any of the experimental tests. Examination of the residual matrices discussed above suggests that there are enough substantially large residuals to justify searching for additional factors unique to experimental tests in order to better account for the correlations among items in these tests.

A second perspective on the relationship of the experimental tests to the factors extracted from the operational tests can be gained by noting the contribution made by each operational factor in terms of the proportion of each experimental test's total and common variance accounted for. Table 5 shows the contribution each operational factor makes to explaining the common and total variance of each experimental test. From this perspective, the letter sets test is much better explained than it was in terms of the residual correlations among its items. Analysis of explanations and evaluation of evidence tests, on the other hand, are much less well explained. In terms of

Table 5

Contribution of Operational Factors in Terms of Variance Explained by Orthogonal Solutions

Test	Number of Items	Total Common Variance	Common Variance as % of Total Variance	Contribution of Factor[c] I	II	III	IV	V	VI	VII	VIII	Total Contribution made by Operational Factors	Total Contribution as % of Total Exp. Variance	Total Contribution as % of Total Common Variance
X_{21} (Letter Sets)	40	27.63	69.0	4.40	4.21	0.10	3.61	0.66	1.13	0.17	0.63	14.91	37.3	54.0%
X_{22}	30	17.04	56.7	2.60	2.22	0.34	0.67	1.04	1.32	0.15	0.64	8.98	29.5	52.8%
1-15 L.R.	15	5.09	33.3	1.77	0.76	0.30	0.07	0.16	0.13	0.09	0.11	3.39	22.6	67.8%
16-30 L.S.	15	12.04	80.0	0.83	1.46	0.04	0.60	0.88	1.19	0.06	0.53	5.59	37.3	46.6%
X_{23}	30	19.36	64.5	2.21	2.66	0.24	1.58	0.32	0.38	0.33	0.65	8.37	27.9	43.2%
1-15 L.S.	15	9.29	61.9	1.02	0.46	0.05	1.24	0.06	0.05	0.25	0.23	3.36	22.4	36.2%
16-30 A.R.	15	10.07	67.1	1.19	2.20	0.19	0.34	0.26	0.33	0.08	0.42	5.01	33.4	49.8%
X_{24} Eval. Evidence	40	14.56	36.4	3.33	0.78	0.34	0.45	0.91	0.87	0.27	0.32	7.25	18.1	49.8%
X_{25} Analysis of Exp.	40	14.84	37.1	2.78	1.94	0.19	0.44	0.37	0.26	0.18	0.19	6.35	15.9	42.8%
Y_1 Logical Diagrams	50	26.81	53.6	6.78	4.11	0.49	0.47	0.89	0.96	0.11	0.14	13.95	27.9	52.1%
Y_{10} Deductive Reasoning	20	7.70	38.5	2.16	0.54	0.04	0.07	0.67	0.42	0.08	0.07	4.05	20.3	52.6%

[c]The contributions for tests X_{21} - X_{25} are for the factors from operational form A; those for tests Y_1 and Y_{10} are for factors from form B. The reader should consult Table 3 above to identify the factors in each form.

percentage of variance explained by operational factors, the ordering of the tests would change slightly. The logical reasoning items continue to be the relatively best explained item type.

A summary of the common variance explained in each test by type of operational factor--verbal, quantitative or speed--is given in Table 6. It can be seen that the letter sets, analytical reasoning, logical diagrams, and especially deductive reasoning item types are explained more by quantitative than verbal factors. The other tests--analysis of explanations, evaluation of evidence, and logical reasoning--particularly the last two, are better explained in terms of verbal factors than in terms of quantitative ones. The relatively high contribution of speed factors to the explanation of the evaluation of evidence test suggests that there may be too many items (40) for the time allowed (25 minutes) on this test. Examination on item statistics confirms this speededness, showing that fewer than 90% of examinees attempt any of the items in the last quarter of the test.[d]

Overall, there remains in each experimental test a substantial portion of unexplained common variance. As a baseline it is again useful to consider comparable figures obtained for the eight experimental tests analyzed in the previous study. For the least well explained test in that study, the operational factors accounted for 65% of the experimental test's common variance. In each of the other seven experimental tests investigated in that study, the operational factors explained more than 75% of the common variance and fully 90% in one quantitative test containing regular quantitative items.

In this study, the test that has its common variance best explained, the logical reasoning test, is explained only about as well (67.8%) as the least well explained test from the previous study. Typically, in the present study it was common for operational factors to explain from about 45 to 55% of an experimental test's common variance, a figure considerably lower than the typical 75 to 85% figure computed for the previously studied experimental tests.

In summary, from the perspective of both the amount of variance accounted for and the extent to which interitem correlations were reproduced by operational factors, the decision to factor analyze experimental tests' residual matrices seemed justified. The factor analysis of residual matrices is discussed later in this report.

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[d] A sample passage and set of items were considered an important part of the directions. Thus, the test contains 40 operational items but also five sample items and a very short passage. If it were possible to eliminate this sample set, the speededness might be somewhat less marked.

Table 6

Percentage of Experimental Test Common Variance Explained by Type of Operational Factor (Orthogonal)

Experimental Test	Content	Percentage of Test's Common Variance Accounted for by Type of Factor Type[e]	Percent
X_{21}	Letter Sets	Quant.	28.9
		Verbal	18.6
		Speed	6.5
X_{22}[f]	Logical Reasoning	Quant.	8.4
		Verbal	43.6
		Speed	5.8
X_{23}[f]	Analytical Reasoning	Quant.	26.0
		Verbal	17.9
		Speed	5.9
X_{24}	Evaluation of Evidence	Quant.	10.2
		Verbal	27.4
		Speed	12.2
X_{25}	Analysis of Explanations	Quant.	17.3
		Verbal	21.3
		Speed	4.2
Y_1	Logical Diagrams	Quant.	29.1
		Verbal	17.7
		Speed	5.4
Y_{10}	Deductive Reasoning	Quant.	37.8
		Verbal	8.4
		Speed	6.4

[e]All quantitative, all verbal, and all speed factors have been grouped together, respectively. Although the general quantitative factor appears to have a component of speed associated with it, it is considered in the quantitative category here. The category labeled speed here contains only the two factors identified and labeled as speed factors in the preceding analyses.

[f]The letter sets portions of these tests have been omitted from this description.

Factor Analyses of Residual Matrices: Varimax and Oblimin Solutions

As stated previously, the residual matrices for each experimental test were deemed to be sufficiently large in terms of both the number and size of residuals and the amount of unexplained variance to justify factor analyzing each of these matrices. Inspection of roots and trial rotation of two and three factors resulted in two-factor (minres) solutions for each of the seven experimental tests. The factor loadings for each test and the amount of variance contributed by each factor are described below for these factors, which represent the unique, interpretable dimensions among the items within each of these tests above and beyond the common factors found in the current operational forms.

X_{21} Letter Sets. Two interpretable orthogonal factors were extracted from the experimental test containing only letter set items. The first factor must be described as a general letter sets dimension, since it is defined by high loadings (greater than .30) from each of the first 25 items in the test. Fourteen of the remaining 15 items have loadings greater than .30 on a second factor, nearly as large as the first, which is clearly associated with the speededness of the test.

The direct oblimin (quartimin) solution is very similar to the varimax solution for this test, and the interpretation remains the same. The oblique solution shows a correlation of .38 between the general letter sets factor and the speed factor.

X_{22} Logical Reasoning/Letter Sets. Analysis of test X_{22}, which contained both logical reasoning and letter sets item types, revealed one factor characterized by high loadings (all but one greater than .40) from letter sets items that occupied the second half of the test.

The second factor, less than half as large as the first, was characterized by slight negative loadings from items at the beginning of the letter sets portion of the test. The size of loadings from letter sets items gradually increases until these loadings become large and positive at the end of the test, suggesting interpretation of this factor as an ability to respond quickly to letter sets items. No loadings greater than .20 from any of the logical reasoning item types were observed, suggesting again that these items contribute little beyond the skills already tapped by the verbal and quantitative sections of the Aptitude Test.

The oblique solution is practically identical with the orthogonal one, with only a .13 correlation between the two factors.

X_{23} Letter Sets/Analytical Reasoning. The most prominent factor extracted from the residual matrix for test X_{23} was one clearly associated with the letter sets item type, which appeared this time in the first half of the test. A majority of the loadings from these items was greater than .60.

The second factor, less than half as large, was defined by analytical reasoning items, which were positioned in the second half of the test. Since items became relatively speeded about halfway through the second portion of the test, interpretation is not as straightforward as it is in certain other tests. Highest loadings on this factor came from one set of five items in the middle of the analytical reasoning portion of the test. Three of these items have loadings higher than .60. Since loadings from final items are considerably smaller, the pattern is suggestive of a factor defined by analytical reasoning items. The fact that the factor is largely defined by items in a single set (one dealing with family relationships) suggests a dimension that may be best measured by items containing rules of this nature.

The oblique solution is virtually identical with the orthogonal one, since the two oblique factors are uncorrelated (.03).

X_{24} Evaluation of Evidence. Two relatively minor factors were extracted from the residual matrix obtained for the evaluation of evidence test. The first was a clearly identifiable speed factor characterized by very high loadings from the final nine items, beginning at the point where the test becomes speeded. A second minor factor was defined by the keyed choices for these items. Negative loadings were noted on all 13 items whose correct answers were either choice A, "if the statement either proves the conclusion or makes it almost certainly true" or choice C, "if the statement either disproves the conclusion or makes it almost certainly false" and positive loadings on 14 of 17 items keyed as choice B, "if the statement supports the conclusion but does not make it almost certainly true" or choice D, "if the statement weakens the conclusion but does not make it almost certainly false." The similarity between choices A and C and B and D is obvious, each being the converse of the other. Thus, one way to distinguish among evaluation of evidence item types is to decide whether they deal with "black and white" choices as exemplified by options A and C or whether they fall in a grayer area requiring more judgment than logic.

The oblimin solution is nearly the same as the one produced by varimax rotation. A negligible correlation of .03 between oblique factors was noted.

X_{25} Analysis of Explanations. The first of two factors extracted from the residual matrix of this test was one that is clearly associated with item choice D, the keyed choice for statements that are relevant facts, as opposed to ones that are inconsistent statements, possible explanations, additional deducible facts, or irrelevant facts. Of the 12 items having loadings greater than .20 on this factor, 11 come from the 14 items whose correct answer is choice D. A possible explanation of this phenomenon is that, since these items require elimination of choices in the order A, B, C, D, E until the first choice that cannot be eliminated is correct, the item may require more time or be more difficult than those having earlier (A, B, C) keyed choices. However, item statistics do not show that choice D items are more difficult than others. Furthermore, the fact that items keyed as choice E do not load on this factor suggests that the additional time hypothesis

is not tenable. Another hypothesis regarding this pattern of loadings is that certain items, namely those keyed as choice D, measure examinees' understanding of the sequential process required in answering questions. The statements given in items keyed as A, B, or C are relevant ones. However, "relevant" is not the correct answer because each statement is something else first--either an inconsistent statement, a possible explanation, or an additional deducible fact. Thus examinees who view the five choices as competing equally, instead of considering them in a sequential fashion, would be likely to answer items incorrectly.

The second factor is defined by loadings from items whose keyed choices are either A, an inconsistent statement, or B, a possible explanation. Fourteen of 17 loadings greater than .20 come from the 17 items whose keyed choices are either A or B.

Again, the oblique and orthogonal solutions are virtually identical, with only a .02 correlation between oblique factors.

Y_1 Logical Diagrams. The most prominent dimension extracted from the matrix of residual correlations among logical diagram items was one associated with the speededness of the test. The gradual increase in the size of loadings corresponds fairly closely to the percentage of examinees attempting each item. Loadings begin to increase at about the three-quarter point in the test.

The second factor seemed to be defined best by two particular item choices, B and D, each of which represented the same relationship for each item in the test. The other choices were not consistently the same; i.e., they did not represent the same relationship for each item throughout the test and therefore could not define a factor. Nonetheless, there is evidence here, as there was for previously discussed tests, for the contribution made by item choices.

Under oblique rotation, interpretation of factors remains the same. However, the two oblique factors are moderately correlated (.38), suggesting that the two minor dimensions unique to this test are related.

Y_{10} Deductive Reasoning. Two relatively insignificant factors were retained for test Y_{10}. The first seemed to reflect the ability to respond rapidly to this item type, high loadings (greater than .20) coming from items in the last half of the test and beginning at the point at which the test becomes relatively speeded. The second factor is best defined by loadings from those items that are easiest. There appears to be, therefore, no unique dimension that can properly be thought to be a deductive reasoning ability that is unique to this test.

The oblique solution, which yielded only a slight correlation of .17 between factors, is essentially the same.

In summary, some of the residual factors associated with experimental tests may reflect a variety of things such as response set, peculiarities in item structure, or position in which items are placed. The major finding is that all tests but logical reasoning seem to have a unique dimension.

Oblique Solutions for Operational Forms

As stated above, oblique as well as orthogonal solutions were obtained for each of the operational forms. The factor pattern and factor structure matrices are summarized in Appendix D.

The interpretation of factors remains substantially the same when subjected to oblique rotation. For form A of the test, the only major interpretive change concerns Factor II, general quantitative, and Factor IV, quantitative: easy algebra. Under oblique rotation these factors become more clearly differentiated on the basis of item difficulty. About half of the quantitative items have their highest loadings on Factor II and about half on Factor IV, with the most difficult items loading on Factor II, the most prominent factor with respect to the proportion of the test's common variance accounted for. The table below shows the correlation among oblique factors.

Table 7

Correlations among Oblique Factors (Form A)

	Factor	I	II	III	IV	V	VI	VII	VIII
I	Reading Comp.	1.00							
II	General quant.: difficult	.19	1.00						
III	Vocab.	.31	.16	1.00					
IV	Quant.: easy	.34	.51	.03	1.00				
V	Speed: discrete verbal	.53	.27	.42	.29	1.00			
VI	Reading speed	.49	.29	.23	.32	.55	1.00		
VII	Data Interp.	.28	.18	.07	.29	.29	.32	1.00	
VIII	Reading Comp.: specific	.40	.06	.27	.19	.30	.25	.24	1.00

As shown above, several of the factors exhibit substantial relationships with others. The two speed factors are highly related (.55). Reading Comprehension is also highly related to each of these speed factors. In fact, it appears slightly more highly related to performing rapidly than to either of the other verbal factors, although these latter factors are fairly highly correlated with the reading comprehension factor (vocabulary = .31; reading comprehension: specific = .40).

The two general quantitative factors are correlated substantially (.51), as might be expected, but neither is very highly related to the data interpretation factor, suggesting relative independence of this type of quantitative ability.

Correlations between verbal and quantitative factors are in general fairly low, suggesting the relative independence of these two global ability types. The highest correlation between any pair of verbal and quantitative factors was for reading comprehension and easy quantitative (.34), reflecting possibly the most "fundamental" group of aptitude questions least affected by background.

The interpretation of the orthogonal factors found in form B is confirmed by the oblique solution. Interpretation remains the same for each factor. In some instances, interpretation is slightly more straightforward in the oblique case than in the orthogonal. One slight change that is noted is that Factor VII, data interpretation: extraction and manipulation, also has moderate loadings from several practical application/word problems. These items loaded on the general quantitative factor for the orthogonal solution. The correlations among the oblique factors extracted from form B are shown below.

Table 8

Correlations among Oblique Factors (Form B)

	Factor		II	III	IV	V	VI	VII	VIII
I	General quant.	1.00							
II	Reading Comp.	.18	1.00						
III	Vocab.	.09	.40	1.00					
IV	Speed: discrete verbal	.23	.32	.42	1.00				
V	Data interp.: algebra	.40	.34	.02	.15	1.00			
VI	Reading speed	.33	.41	.28	.44	.27	1.00		
VII	Data interp.: extraction and manipulation	.58	.32	.24	.31	.28	.35	1.00	
VIII	Easy opposites	.03	.24	.06	.23	.24	.20	.13	1.00

Factor I, general quantitative, has substantial correlations with the other two quantitative factors related to data interpretation. The correlation with data interpretation: extraction and manipulation is very high (.58). The speed factors are also highly correlated (.44).

The vocabulary factor is correlated slightly higher with reading comprehension in form B (.40) than in form A (.31). This may be due to increased reliability resulting from the additional analogy and opposites items in form B.

The highest correlation between any verbal and quantitative factors (.34) is for reading comprehension and the data interpretation factor

(Factor V) defined by the algebraic table. Although the items defining Factor V do not look like they have much in common with reading comprehension items, both item types may have a common link in the respect that they both would seem to require fairly careful consideration and understanding of stimulus material before questions can be answered.

In summary, even using oblique rotation according to the oblimin criterion (quartimin) that results in the most highly correlated factors, the verbal and quantitative factors remain quite independent, suggesting the independence of the two global abilities tapped by the GRE Aptitude Test, and vocabulary remains relatively independent of reading comprehension. A next step would have been to investigate a hierarchical solution based on the oblique factors. However, this would have little effect on the residual factors discussed above, the procedure was omitted.

Description of Experimental Tests in Terms of Operational Factors (Oblique Solution)

Primary factor extension matrices for each of the experimental tests, when oblique factors are extended, were examined along with the factor structure extension matrices. Each test is described below in terms of the oblique factor solutions computed for each operational form. Both the pattern and structure matrices have been considered in interpreting the solution for each operational form. The discussion below, however, focuses primarily on the pattern matrix, since emphasis is on a factor's contribution to performance on the experimental items when considered as a set rather than on the relationship between individual factors and items.

X_{21} Letter Sets. Letter sets items load somewhat differently on the factors derived from the oblique rotation than on the orthogonal factors. The major difference is the items type's relationship to oblique Factor IV, which, under oblique rotation, was interpreted as an easy quantitative factor. Nearly all (38 of 40) letter sets items, which were quite easy for most examinees, load higher on this easy quantitative factor than on any other. Seven items have loadings greater than .40. Factor I, reading comprehension, on which the majority of items had their highest loadings in the orthogonal solution, continues to have 16 loadings greater than .20 but has only one item loading highest on this factor. Factor VI, reading speed, has nearly as many (15) loadings greater than .20. Examination of the structure matrix confirms the importance of these three factors with respect to performance on letter sets items. Items are most highly correlated with Factor IV, followed by Factor VI, and then Factor I. Thus elementary quantitative ability and, secondarily, the ability to deal with connected discourse (especially the ability to process it rapidly) appear to contribute most to performance on the letter sets item type.

X_{22} Logical Reasoning. The fifteen logical reasoning items in test X_{22} do not exhibit consistently high pattern loadings on any of the oblique operational factors, although there is a slight tendency for higher loadings to appear on Factor I, reading comprehension. This tendency is not as pronounced as it was for the orthogonal factor solution. With respect to the correlation of logical reasoning items with factors,

the structure extension matrix shows that the speed factors, Factor V and Factor VI, are as highly related to performance on these items as reading comprehension ability is. When contrasted with the description of logical reasoning performance in terms of orthogonal factors, the interpretation in terms of oblique factors suggests that reading comprehension ability is lightly less important but that speed may be slightly more important.

X_{23} Analytical Reasoning. The 15 analytical reasoning items occupy the second half of test X_{23}. Five items have their highest loadings on Factor IV, easy quantitative. These items tend to be the easiest ones. Four of the most difficult items load highest on the difficult quantitative factor, Factor II. Factor I, reading comprehension, has three items loading highest on it as well as eight items with loadings greater than .20. The factor structure extension matrix shows that Factor II is most highly related to performance on this item type and that Factors I and IV are also fairly highly related. The description in terms of oblique factors is in general, therefore, quite consistent with the orthogonal description.

X_{24} Evaluation of Evidence. Description of the evaluation of evidence test in terms of oblique factors is generally consistent with its description with respect to orthogonal factors. Twelve of the items have highest loadings on Factor I, reading comprehension. Speed factors V and VI also have a relatively large number of items having their highest loadings on these factors, nine and eight. These speed factors also have a relatively large number of loadings greater than .20. In fact, each has more than Factor I does. Inspection of the factor structure extension matrix confirms the importance of these three factors, again suggesting that speed may be as important as reading comprehension.

X_{25} Analysis of Explanations. Description of test X_{25} in terms of its relationship to oblique factors shows it to be somewhat less related to reading comprehension than it was when described with respect to orthogonal factors. The second factor, difficult quantitative, also has a modest number of relatively high loadings, as it did in the orthogonal description. The factor structure extension matrix reveals that Factors I, II, IV, V, and VI all correlate with performance on this item type, though none bears a very high relationship.

Y_1 Logical Diagrams. Logical diagram items continue to load consistently on the general quantitative factor when interpreted in relation to oblique factors. A majority (35 of 50) of items still have highest loadings on this factor. The next most influential factor is reading speed, Factor VI, with nine items loading highest on this factor. Factor II, reading comprehension, appears considerably less important to performance on this item type when an oblique solution is considered. Examination of structure extension correlations shows that Factor II, reading comprehension, and Factor V, data interpretation related to an algebraic table, are also moderately related to logical diagram performance.

Y_{10} Deductive Reasoning. Conclusions about the operational factors underlying the deductive reasoning test are similar for both the orthogonal and the oblique solutions. In the oblique case considered here, half of the 20 deductive reasoning items have highest loadings on the general quantitative factor. Five of the remaining ten load higher on the data interpretation factor associated with a specific algebraic table. Inspection of the factor structure extension matrix supports the importance of these two factors.

Since the eight factor solutions span the same space, the residual matrices for experimental tests are identical regardless of which factors, oblique or orthogonal, are removed. Likewise, the variance explained by operational factors is also the same for both solutions. The proportional contribution made by each factor, however, changes depending on which solution is considered. The contribution made by each oblique factor to explaining the variance in each experimental test is given below in Table 9 and summarized in Table 10.

Comparing the entries in Table 10 with those in Table 6, which shows the contribution made by orthogonal factors to explaining experimental test variance, several consistent trends appear. The first is that quantitative factors account for approximately the same percentage of experimental test common variance regardless of which solution, oblique or orthogonal, is used. Deductive reasoning continues to appear to be the most quantitative of any experimental test. Letter sets, logical diagrams, and analytical reasoning seem again to be the next most quantitative in nature. The second trend is for speed factors to explain more, and verbal factors less, of the common variance of each experimental test. The percentage attributable to speed is about twice as much, in general, when oblique factors are considered. Speed factors become even more important in the evaluation of evidence test, accounting for more of that test's common variance than V and Q factors combined. The part speed plays in responding to letter sets items also becomes considerably more apparent. The set effect on the analysis of explanations test is to make it appear more quantitative than verbal in nature, since quantitative factors account for more of the test's variation with an oblique solution. With the orthogonal solution, verbal factors explained a slightly larger percentage of variance than quantitative factors did.

Contributions of Experimental Tests in Terms of Additional Variance

Another way to assess the value of the experimental tests in terms of their independence of the current Aptitude Test is to determine the amount of common variance among the items in each test after statistically removing the contribution made by operational test factors. Columns (5) and (6) in Table 11 contain figures relevant to this assessment. Column (5) shows the estimated total common residual variance for each test after the contribution made by operational factors has been removed. Column (6) presents another indication of the remaining common variance

Table 9

Contribution of Oblique Operational Factors in Terms of Experimental Test Variance Explained

	Test	Number of Items	Total Common Variance	Contribution of Factor								Total Contribution
				I	II	III	IV	V	VI	VII	VIII	
X_{21}	Letter Sets	40	27.63	2.90	0.57	-0.05	6.75	0.99	2.99	0.69	0.08	14.92
X_{22}	Logical Reasoning	15	5.06	0.95	0.52	0.17	0.15	0.20	0.66	0.18	0.48	3.31
X_{23}	Analytical Reasoning	15	10.07	1.18	1.35	0.12	0.92	0.49	0.64	0.24	0.09	5.03
X_{24}	Evaluation of Evidence	40	14.56	1.58	0.29	0.14	0.49	1.63	2.14	0.59	0.40	7.24
X_{25}	Analysis of Explanations	40	14.84	1.65	1.25	0.01	0.82	0.94	0.75	0.53	0.41	6.36
Y_1	Logical Diagrams	50	26.81	4.96	2.07	0.17	0.77	2.36	2.43	0.73	0.45	13.95
Y_{10}	Deductive Reasoning	20	7.70	1.42	0.18	-0.01	0.05	1.09	0.76	0.45	0.11	4.05

Table 10

Percent of Experimental Test Common Variance Explained by Type of Operational Factor (Oblique)

Experimental Test	Content	Percent of Test's Common Variance Accounted for by Type of Factor		
		Type	Total Explained	Percent of Common
X_{21}	Letter Sets	Quant.	8.01	29.0
		Verbal	2.93	10.6
		Speed	3.98	14.4
X_{22}	Logical Reasoning	Quant.	0.85	17.0
		Verbal	1.60	32.0
		Speed	0.86	17.2
X_{23}	Analytical Reasoning	Quant.	2.51	24.9
		Verbal	1.39	13.8
		Speed	1.13	11.2
X_{24}	Evaluation of Evidence	Quant.	1.37	9.4
		Verbal	2.12	14.6
		Speed	3.77	25.9
X_{25}	Analysis of Explanations	Quant.	2.60	17.5
		Verbal	2.07	13.9
		Speed	1.69	11.4
Y_1	Logical Diagrams	Quant.	8.05	30.0
		Verbal	2.69	10.0
		Speed	3.20	11.9
Y_{10}	Deductive Reasoning	Quant.	2.96	38.4
		Verbal	0.28	3.6
		Speed	0.81	10.5

Table 11

Summary of Experimental Test Variance Explained by Operational and Residual Factors

(1) Experimental Test		(2) Total Variance	(3) Estimated Total Common Variance	(4) Total Common Variance Explained by Operational Factors	(5) Estimated Total Common Residual Variance	(6) Total Common Residual Variance Explained by 2 Residual Factors	(7) Index (5)÷(4)	(5)÷(4)
X_{21}	Letter Sets	40	27.63	14.91	14.08	10.36	.94	.69
X_{22}	Total	30	17.04	8.98	8.89	6.31	.99	.70
	Logical Reasoning	15	5.00	3.39	2.44	0.34	.72	.10
X_{23}	Total	30	19.36	8.37	11.37	7.15	1.36	.85
	Analytical Reasoning	15	10.07	5.01	5.31	2.04	1.06	.41
X_{24}	Evaluation of Evidence	40	14.56	7.25	10.50	5.83	1.45	.80
X_{25}	Analysis of Explanations	40	14.84	6.35	9.65	5.14	1.52	.81
Y_1	Logical Diagrams	50	26.81	13.95	13.67	8.49	.98	.61
Y_{10}	Deductive Reasoning	20	7.70	4.05	4.32	2.84	1.07	.70

in each experimental test, the variance explained by the two-factor solutions computed from the residual matrices for each experimental test. To allow us comparisons among tests, each figure has been given in column (7) as a percentage of the total common variance of the test explained by operational factors. Thus these latter indices can be thought of as reflecting the extent to which factors or dimensions common to experimental tests explain the variation in these tests in relation to the extent to which operational factors explain that variation. These figures show that the logical reasoning test has the least residual common variance in relation to the amount of its common variance explained by the factors underlying the operational test, whereas the analysis of explanations and evaluation of evidence tests have the most.

Summary of the Independence of Experimental Tests

Various statistics related to the residuals among experimental test items, the variance explained by operational factors, and the total common and common residual variance among experimental items have been discussed above. The present section contains three figures summarizing most of these statistics. The first (Figure 1) is simply a plot showing for each test the percentage of its total and the percentage of its common variance explained by the factors in the operational test. A 45° line has been drawn to represent the degree to which each test is explained. In general, Figure 1 shows that the experimental tests are clustered fairly closely, with letter sets and logical reasoning being somewhat better explained in terms of operational factors than the analysis of explanations and evaluation of evidence tests are. Since there is relatively little variation among tests with respect to this criterion, however, the relative ordering of tests should be interpreted somewhat cautiously.

Figure 2, the plot of diagonal and off-diagonal residuals for each test, exhibits a greater degree of variation among the experimental tests. The logical and deductive reasoning tests lie at one end of the 45° axis and the letter set test at the other. The remaining tests are nearer the middle of the axis with the correlations among logical diagram and analytical reasoning items being somewhat less well reproduced than the correlations among evaluation of evidence items and analysis of explanations.

Figure 3, suggests that, in terms of the relative contribution made by operational factors and residual common factors (or estimated common residual variance), the analysis of explanations and evaluation of evidence item types are by far the most unique, the logical reasoning type by far the least. The remaining item types cluster together about midway between the extremes.

Figure 4, showing the plot of each test with respect to the percentage of its common variance explained by verbal and quantitative operational factors, suggests that the logical reasoning test is the most verbal in nature and that deductive reasoning is the most quantitative. Logical diagrams, letter sets, and analytical reasoning are slightly

Figure 1

Percent Experimental Test Variance Accounted for
by Operational Factors

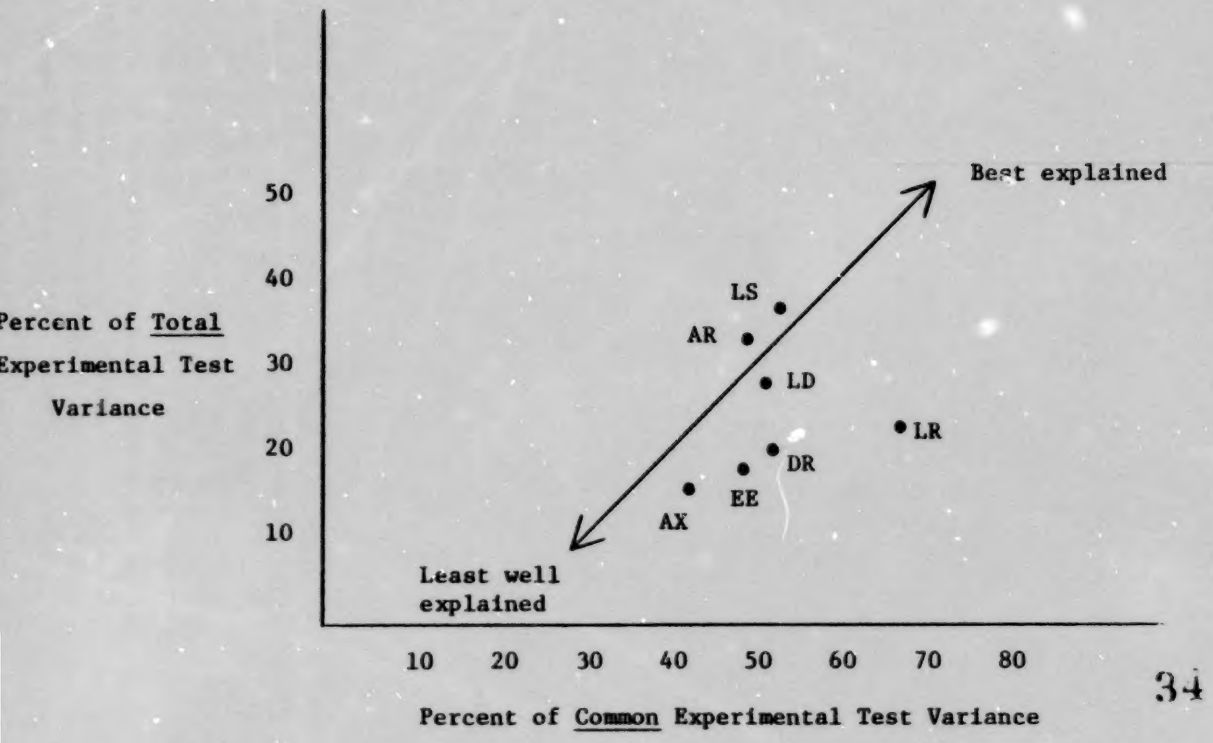


Figure 2

Frequency of Small Residuals by Experimental Test

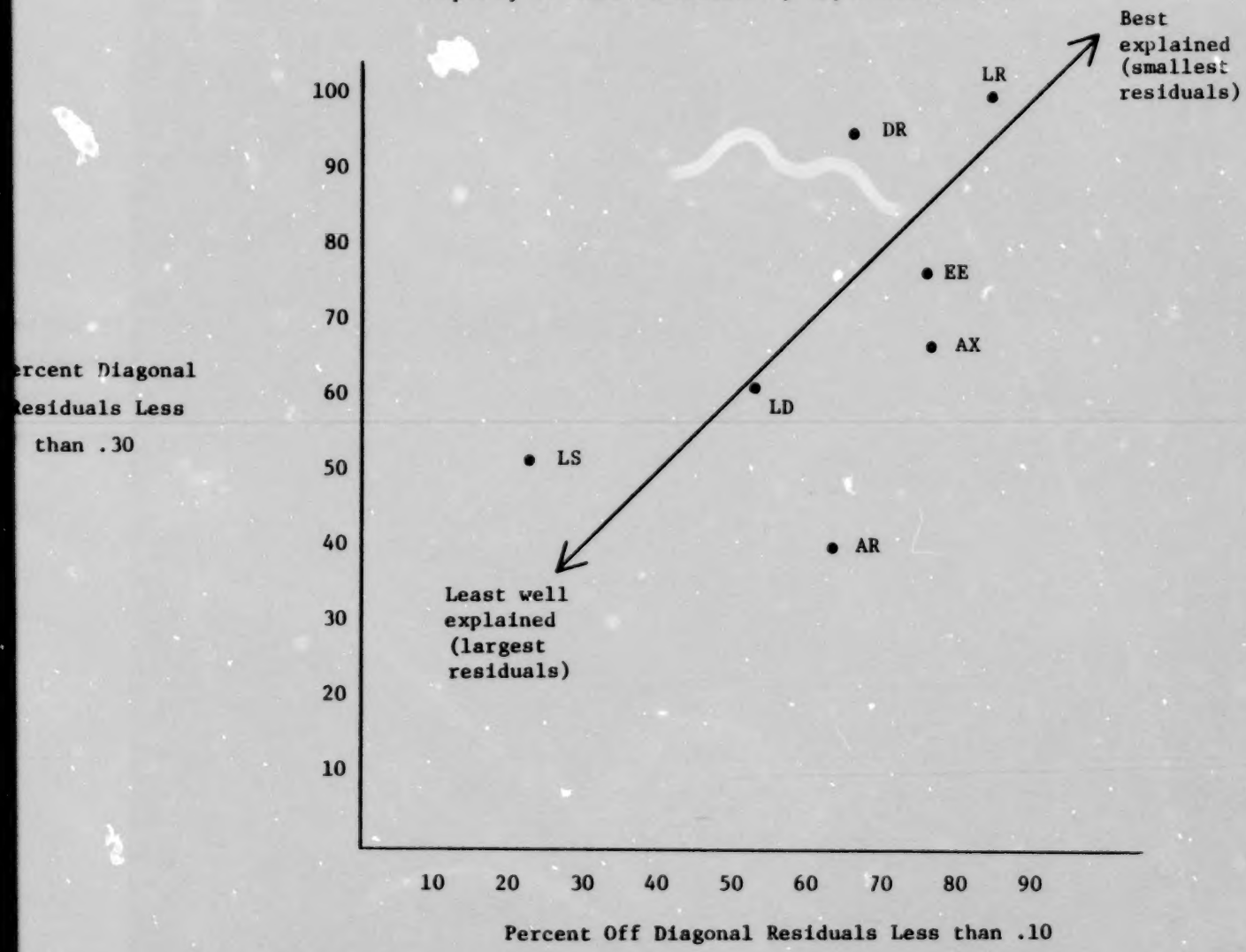


Figure 3

Residual Common Variance for Experimental Tests as a Percentage of Common Variance Explained by Operational Factors

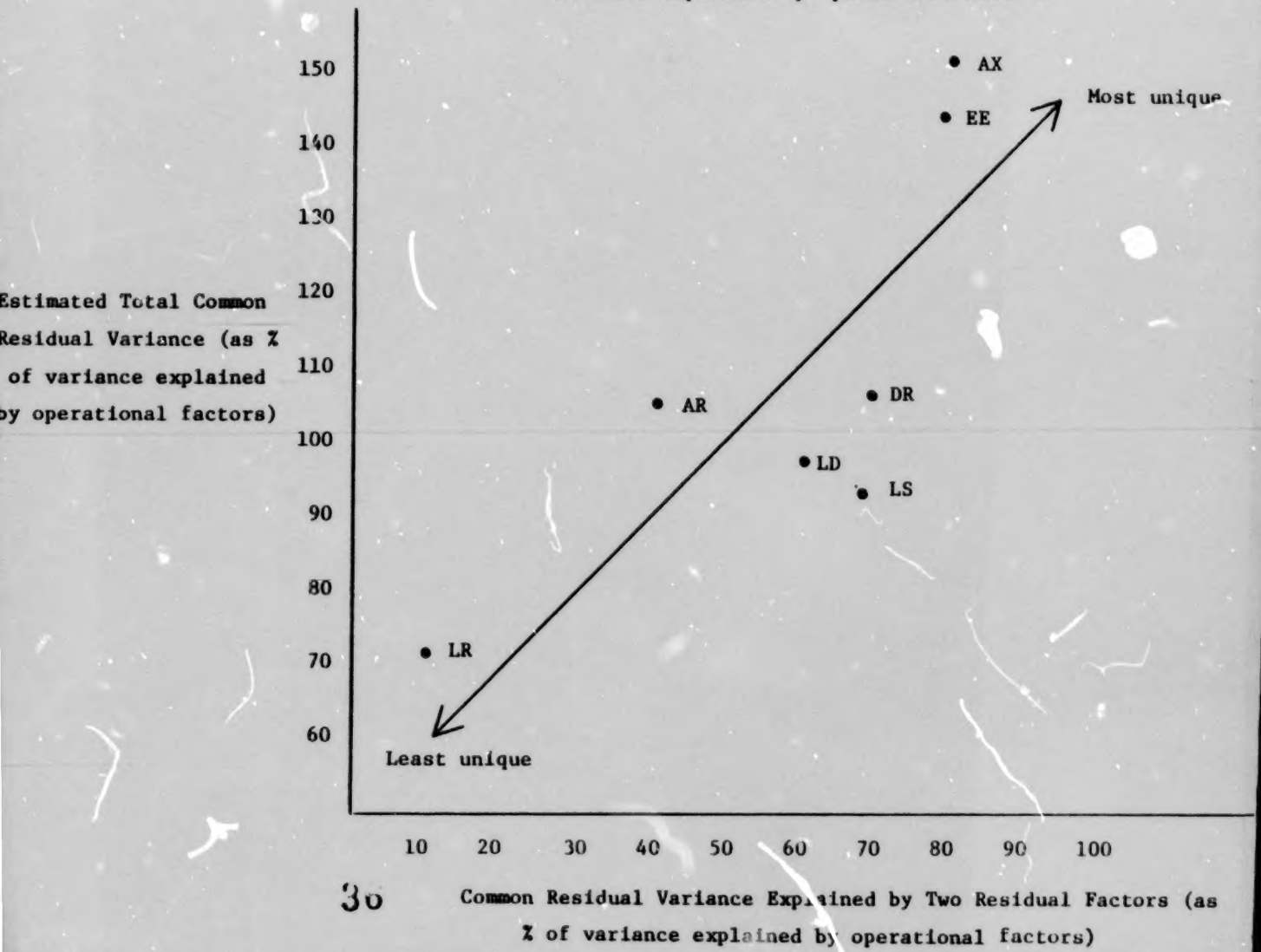
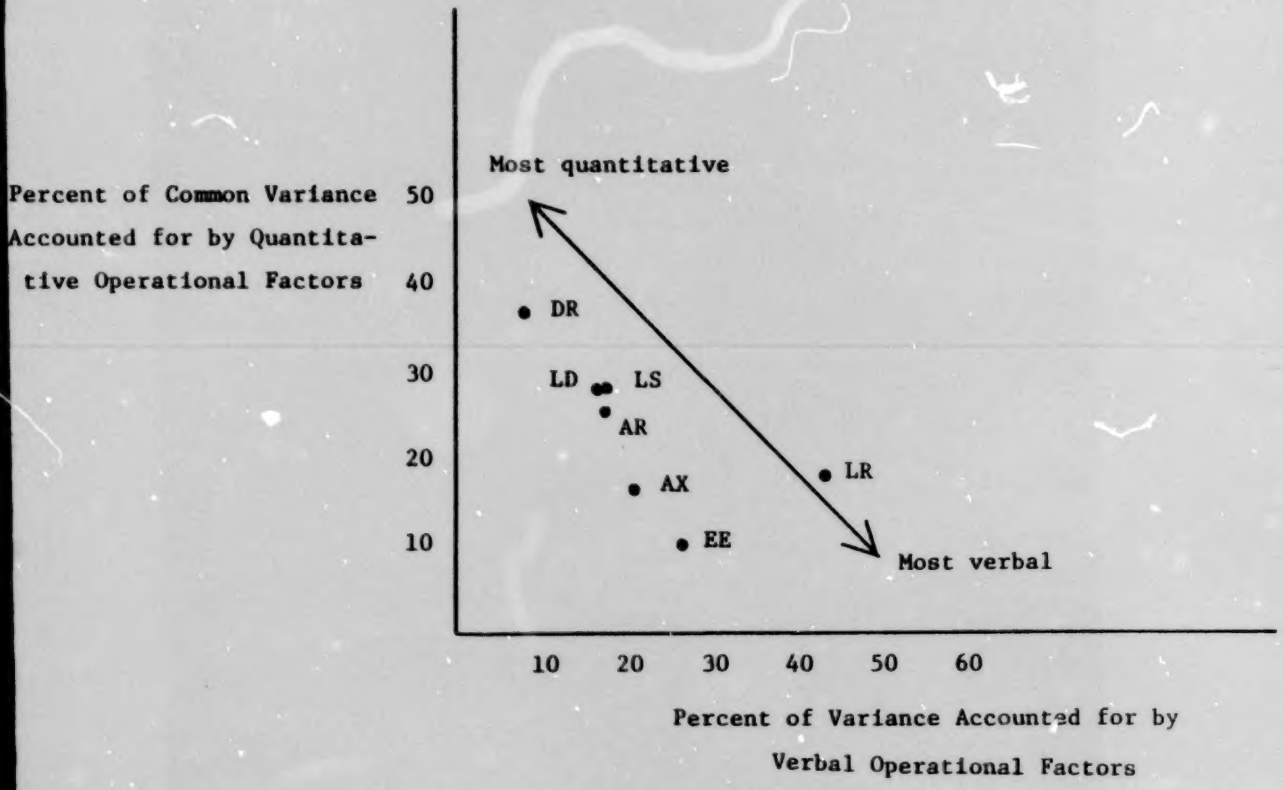


Figure 4

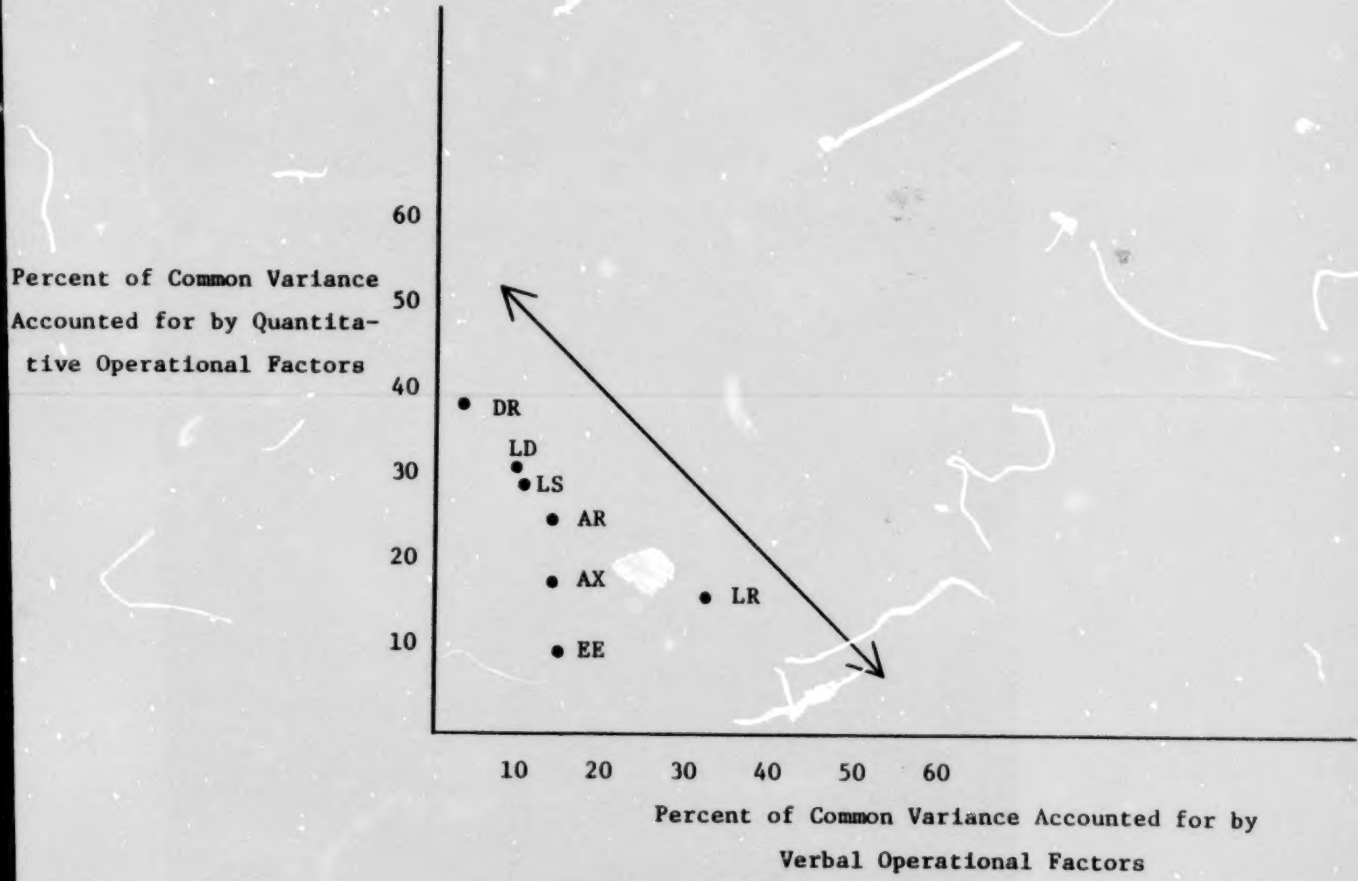
Comparison of Variance Explained by Verbal and Quantitative Operational Factors
Each Experimental Test (Orthogonal Factors)



more quantitative than verbal in nature, whereas analysis of explanations and evaluation of evidence are slightly more verbal. Figure 5 shows about the same pattern when oblique factors are considered.

Figure 5

Comparison of Variance Explained by Verbal and Quantitative Factors f
Each Experimental Test (Oblique Factors)



SUMMARY

In order to investigate the characteristics of seven experimental abstract reasoning tests, factor extension analyses (both orthogonal and oblique) were computed for each test. The factor extension analyses included:

(1) estimates of the loadings of each experimental test item on factors extracted from the operational factors,

(2) estimates of the contribution made by each operational factor to explaining the common and total variance of each experimental test,

(3) estimates of the extent to which the operational factors were capable of reproducing the intercorrelations of items within each test,

and (4) computation of unique, interpretable dimensions found in experimental tests, but not in the operational forms.

The operational forms analyzed yielded solutions that were comparable to a previously reported factor analysis. Three global factors--two verbal and one quantitative--which accounted for about three quarters of the common variance, were extracted from each form. Less prominent factors or clusters were associated with the speededness of each separately timed verbal section of the test. Still other less prominent dimensions were related to various aspects of test content and may be form-specific.

Loadings of experimental items on operational factors showed that the most prominent dimension underlying the logical diagrams, the deductive reasoning, and the operational test is general quantitative ability. General quantitative ability of a more elementary nature is most prominent in the letter sets test. The analytical reasoning test also seems, to a lesser degree, to contain a general quantitative component and somewhat less of a reading comprehension component. The logical reasoning test appears relatively more dependent on reading comprehension than on any other ability. Performance on both the evaluation of evidence and analysis of explanations item types also seems to rely more on reading comprehension ability, although there is also some hint of a general quantitative trait underlying performance on the latter type.

When each test is considered in light of the percentage of its variance, both common and total, explained by operational factors, differentiation among the tests is somewhat difficult. The common variance in the logical reasoning test and the total variance in the letter sets test are relatively best explained, though there remains considerable unexplained variance in each of the seven tests. The variance of the analysis of explanations test is explained least well of any of the tests.

Reproduction from operational test factors of the matrix of inter-item correlations for each experimental test was best for the logical reasoning test, next best for the deductive reasoning test, and worst for letter sets.

Factor analyses of residual matrices revealed that all tests but one, logical reasoning, have at least one unique common dimension, i.e., a common factor not shared with the operational test. The analysis of explanations test seems "most unique" since both of the factors extracted from its residual matrix were associated with this item type. The letter sets test has one factor, a fairly substantial one, associated with item type as does the analytical reasoning test. The remaining tests, however, do not exhibit particularly strong unique dimensions. The most prominent unique dimension in the evaluation of evidence and logical diagrams tests was speed, although each of these tests had a small factor associated with item type. The deductive reasoning test appears to have two unique, but relatively insignificant dimensions, one of which is speed.

From the above analyses there is little to contra-indicate the choice of logical diagrams, analytical reasoning, and analysis of explanations for inclusion in the new analytical module. In many respects the choice of these three item types appears quite good:

(1) All three appear to have unique dimensions unshared with current operational test, although some care may be required to make certain that speed is not the primary contribution of the logical diagrams items. Deductive reasoning and evaluation of evidence types would appear to have been relatively poor or choices with respect to this criterion.

(2) With respect to the extent to which operational factors can reproduce the relationships among items within each experimental test, none of the three item types chosen for the analytical section were particularly well reproduced, suggesting that their structure is different from that of the operational test. The logical and deductive reasoning item types would have been relatively poor choices by this criterion.

(3) With respect to the amount of common and total variance explained by operational factors, none of the three item types seems to have been a poor choice, with the analysis of explanations a very good choice. The logical reasoning type would have been a very poor choice by this standard.

(4) If it is desirable to achieve a balance between the "verbalness" and the "quantitativeness" of the restructured test, the choice of analysis of explanations, analytical reasoning, and logical diagrams seems appropriate. The three types lie about midway between the verbal and quantitative poles, with analysis of explanations being slightly more verbal, logical diagrams lightly more quantitative. Deductive

reasoning could be considered to be too quantitative in nature and logical reasoning and evaluation of evidence too verbal by this standard. It might also, however, be possible to make the case that since both logical diagrams and analytical reasoning items are more highly related to quantitative than to verbal factors, the criterion off balance would suggest that a test slightly more verbal than analysis of explanations, e.g., evaluation of evidence, be selected.

The research reported above has attempted to assess the extent to which seven experimental analytical item types are capable of contributing to the goal of broadened aptitude measurement. Various aspects of the independence of these item types from the current Aptitude Test have been presented and intended for use with other information (validity, reliability, etc.) about these item types. The present research is thought to have resulted in practical information regarding the measurement capabilities of seven analytical item types, several of which will make up an important component of future Aptitude Tests.

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Appendix A

Examples of Experimental Item Types

EVALUATION OF EVIDENCE

Directions: Each of the sets in this section consists of a description of a fact situation and a conclusion based on that situation. Following each conclusion are a number of statements.

Consider each statement separately in relation to the fact situation. Then on the answer sheet blacken space

A if the statement either proves the conclusion or makes it almost certainly true;

B if the statement supports the conclusion but does not make it almost certainly true;

C if the statement either disproves the conclusion or makes it almost certainly false;

D if the statement weakens the conclusion but does not make it almost certainly false;

E if the statement is irrelevant to the conclusion or affects it only slightly.

Sample Set

Between 10:00 p.m. and 11:00 p.m. on October 31, five children were admitted to the Parkside General Hospital. Four were suffering from severe stomach cramps and vomiting. All five had been out "trick or treating" and had eaten a good deal of candy. Doctors at the hospital diagnosed cyanide poisoning and called the police. The police ascertained that only one street, Mavis Avenue, had been canvassed by all five of the children, three in one group and two in another. Their bags of candy were impounded.

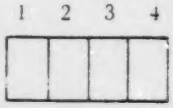
When the residents of Mavis Avenue were interviewed, several mentioned that John Ames, their neighbor, had said, "I'm going to give some kids a Halloween they won't forget." Records at the corner pharmacy indicated that Ames had purchased cyanide on October 29.

Conclusion: Ames poisoned the children.

Sample 1:	Some of the candy remaining in the children's bags contained cyanide. Ames's fingerprints were found on the wrappers of the poisoned candy.	(A) (B) (C) (D) (E)
Sample 2:	All five children remembered going to the Ames house.	(A) (B) (C) (D) (E)
Sample 3:	Ames had given pennies, not candy, to the children.	(A) (B) (C) (D) (E)
Sample 4:	Three of the five hospitalized children did not think they had gone to the Ames house.	(A) (B) (C) (D) (E)
Sample 5:	Several of Ames's friends said that they would vouch for his character.	(A) (B) (C) (D) (E)

DEDUCTIVE REASONING

Directions: The questions in this section are based on diagrams consisting of a rectangle divided into 4 regions.



A plus sign (+) in a region represents the statement that there is something in the region.
A minus sign (−) in a region represents the statement that there is nothing in the region.

There is something in the first region.

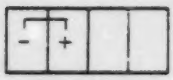
There is nothing in the first region, and there is something in the fourth region.

If a bracket (⌐¬) connects two signs, then one of the signs holds and the opposite of the other sign holds.

is equivalent to either or

If two plus signs or two minus signs are connected by a bracket, then one plus sign and one minus sign must result.

If a plus sign and a minus sign are connected by a bracket, then two plus signs or two minus signs must result.

 is equivalent to either or

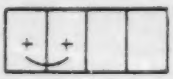
If an arc (‿) connects two signs, then AT LEAST ONE of the signs holds, and BOTH signs may hold.

is equivalent to either

or

or

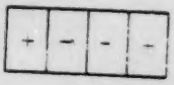
If two diagrams are given, the information in them may be combined in a single diagram.

Given  and then must result.

Sample Question

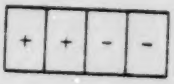
Given and

Which of the following can result?

(A) 

(B)

(C)

(D) 

Sample Answer

Ⓐ Ⓑ Ⓒ ●

LETTER SETS

Directions: Each problem consists of five groups of letters. You are to find, for each group of letters, a pattern that depends only on the relative order in the alphabet of the letters in that group. Then choose the one group whose letters do not show the same pattern as that shown by the letters in the other groups.

EXAMPLE 1

(A) ABCD (B) DEFG (C) JKLN (D) VWXY (E) PQRS

The pattern in groups (A), (B), (D), and (E) can be summarized as follows: The letters in the group are in consecutive alphabetical order. The letters in group (C) do not show this pattern. Therefore, the correct answer is (C).

Each group of letters should be considered independently. Look at relationships within groups instead of relationships between groups. Do not concern yourself with whether the letters fall near or at the beginning or end of the alphabet, or with whether the letters are vowels or consonants. Do not consider differences in the sounds represented by the letters, or the relationship of the letters to any other groups of letters, such as words. Consider only the relative order in the alphabet of the letters in a group.

EXAMPLE 2

(A) CEGI (B) EGIK (C) GIKM (D) IKMP (E) PRTV

The pattern in groups (A), (B), (C), and (E) can be summarized as follows: Each of the four letters is separated from the next by one successive letter. The letters in group (D) do not show this pattern, so (D) is the correct answer. (Note--It would be wrong to choose answer (E) on the basis of the statement: All of the other groups contain the letter I. This statement has nothing to do with the relative order of letters within each of several independent groups.)

LOGICAL REASONING

Directions and Sample Questions

Directions: **The questions in this section require you to evaluate the reasoning contained in brief statements or passages. In some questions, each of the choices is a conceivable solution to the particular problem posed. However, you are to select the one that is *best*, that is, the one that does not require you to make what are by common-sense standards implausible, superfluous, or incompatible assumptions. After you have chosen the best answer, blacken the corresponding space on the answer sheet.**

(The ideas contained in the passages in this section are those of the original authors and do not necessarily represent the opinions of the Law School Admission Council or Educational Testing Service.)

1. **Since all rabbits that I have seen have short tails, all rabbits probably have short tails.**

   Which of the following most closely parallels the kind of reasoning used in the sentence above?

   (A) Since all chemical reactions that I have seen have been undramatic, probably only minor changes took place in the substances involved.
   (B) Since all the human social systems that I have heard of have sexual taboos, all of these sexual taboos have probably had survival value for the human race.
   (C) Since all of the plays of Jovita Maldonado that I have seen feature a spurned lover, probably all of her plays feature this character type.
   (D) Since all eating utensils that I have seen are made of metal, metal is probably the most desirable material for eating utensils.
   (E) Since sight is the most important of man's five major senses, its failure probably seriously affects an individual's aptitude for all formal education.

The given statement reflects inductive reasoning. That is, a generalization about an entire class based on specific observations. The conclusion reached could be criticized because of the limited number of observations, but the question asks only for a recognition of a parallel example of the same kind of reasoning. The question is quite easy.

All the answer choices are similar in some ways, but only one is a statement about specific observations followed by a generalization based on those observations. In (A), (B), and (D), the second part of the statement is not a *generalization* based on the observations mentioned in the first part but is an *explanation* or suggested reason for what was observed. In (E) an assumption is followed by a conclusion. Only (C) refers to specific observations (about some of Maldonado's plays) and proceeds to generalize (about all of Maldonado's plays) on the basis of those observations, however limited they may be. Therefore (C) is the correct answer.

2. **A good hotel can give you a beautiful room for $30 a day, with three meals, and make a profit and pay taxes. And yet a tax-exempt hospital operates in the red for $65 a day. I say it must be bad administration.**

   The author's argument would be considerably weakened if attention were drawn to the fact that

   (A) hotel managers receive better training than do hospital administrators
   (B) the quality of food served by hotels exceeds that of food served in hospitals
   (C) hospitals are run by dishonest administrators
   (D) hospitals provide other services besides room and board
   (E) hospital deficits are a recent phenomenon

This very easy question focuses on the reasonableness of drawing a conclusion from the evidence presented. The author's contention is based on some evidence—the discrepancy between a hotel's and a hospital's operating expenses. The question asks you to identify additional evidence that would weaken the argument that bad administration is responsible for the discrepancy in expenses. (A) and (B) cannot be that evidence because these choices, if true, would actually strengthen the author's argument. (C) is a slightly altered version of the author's own statement of a reason for the discrepancy. (E) could weaken the argument, but only if more information were given. Only (D) provides evidence that casts doubt on the argument. If hospitals provide services other than those mentioned, then the costs of those services rather than bad administration are likely to be the reason for the difference between hotel and hospital expenses. Therefore (D) is the correct answer.

Questions 3-4 **refer to the following passage.**

A servant who was roasting a stork for his master was prevailed upon by his sweetheart to cut off one of its legs for her to eat. When the bird was brought to the table, the master asked what had become of the other leg. The man answered that storks never had more than one leg. The master, very angry but determined to render his servant speechless before he punished him, took the servant the next day to the fields where they saw storks, each standing on one leg. The servant turned triumphantly to the master; but the master shouted, and the birds put down their other legs and flew away. "Ah, sir," said the servant, "you did not shout to the stork at dinner yesterday; if you had, he too would have shown his other leg."

3. **The servant's final retort to his master would be true if which two of the following statements were simultaneously true?**

   I. Roasted storks at the dinner table behave just as live storks in the field do.
   II. The missing leg on yesterday's roasted stork had actually been tucked under the bird.
   III. The master had not undertaken to teach the servant a lesson.
   IV. The servant's sweetheart, rather than the servant himself, had cut off the stork's leg.

   (A) I and II (B) I and III (C) II and III
   (D) II and IV (E) III and IV

The humor of the fable on which these questions are based derives from a logical problem relating to the drawing of conclusions from evidence. The first question is based on the servant's clever retort to his master. The servant's retort is a logical conclusion if certain assumptions are made. The servant's argument—that if the master had shouted at the roasted stork on yesterday's table, it would have shown its other leg as did the storks in the field—assumes that roasted and live storks behave in the same way (I) and also assumes what the servant would like the master to believe, that the missing leg on yesterday's roast had been tucked under the bird (II) rather than eaten by the servant's sweetheart. If (III) were true, the situation leading to the servant's retort would not have occurred; but (III) does not bear on the truth of the servant's retort. (IV) is not the answer because it does not matter who cut off the stork's leg; what is important to the situation is that it was cut off. Thus (A), (I and II), is the correct answer. This question is of about average difficulty.

4. **The servant was able to attack the master's demonstration primarily because the master failed to**

   (A) objectively consider the possibility that storks might have only one leg each

(B) take anyone with him to the fields to confirm his observations
(C) plan later experiments to follow up and validate his tentative findings
(D) reveal to his servant that it was possible for storks to lack one leg and still fly
(E) consider that conditions governing the demonstration were unlike those of the previous day's happening

This question, a moderately easy one, asks for a criticism of the master's demonstration. The master did prove what he had intended to prove—that storks have more than one leg. However, the servant was able to elude the master's "proof" of his guilt by immediately accepting the two-leggedness of storks (including that of a roasted stork) but claiming that the master had simply not treated the roasted and live storks in the same way. Thus (E) is correct because the master's experiment took place under different conditions than did the previous day's experience. (D) is irrelevant to the argument and can be easily eliminated. Choices (A), (B), and (C) all sound as if they might be flaws in an experiment intended to be scientific. But they do not explain why the servant was able to spring back with a new argument. Objective consideration of the possibility that storks might have only one leg each, (A), would not have strengthened the master's demonstration. More observers, (B), or additional experiments, (C), to confirm his findings would perhaps have strengthened his point about live storks but would have had no implications for roasted ones. Thus only (E) can be the answer.

Questions 5-6 **refer to missing portions of the following passage. For each question, choose the completion that is best according to the context of the passage.**

If a book disgusted everyone, no one would read it. However, one can be sure of selling many copies of a book that is publicly proclaimed obscene, for the officially held standards of propriety do not prevail throughout the community. At no point I may be expected to denounce the hypocrisy of the age. I shall not do so. The concept of hypocrisy applies to morals: a person should be good and not merely seem so, and a bad person is little mended by pretense of goodness. But propriety is altogether a matter of how actions appear, so that 5. If a person seems to give no offense, he gives no offense. Why, then, should a society not have public standards of propriety different from those applied by each citizen to his own private conduct? It would be no more absurd to advertise filthy movies by decorous posters than it is to advertise decorous movies by filthy posters; and if a society in which everyone avidly read pornography were to forbid its public sale, that would mean only that it combined a taste for such reading with a taste for 6.

5. (A) bad men rarely succeed in appearing good
(B) the concept of hypocrisy does not apply
(C) actions appear different to observers with different standards
(D) the issue is basically a moral one
(E) the concepts of impropriety and immorality are indistinguishable

Both this question and the next require that you follow the author's reasoning well enough to fill in missing material. The first question focuses on the distinction that the author makes between morality and propriety. The author suggests that propriety, unlike morality, is entirely a matter of appearance and has nothing to do with what is really good or bad. Because the author contrasts morality and propriety, (D) and (E) can be eliminated. (D) assumes that propriety is a moral issue. (E) suggests that impropriety and immorality (and by inference propriety and morality) are indistinguishable. Since "bad" and "good" in (A) refer to morality, (A) does not follow from the author's idea on propriety. (C) is an appealing answer, since it focuses on the way actions appear in public. But (C) does not follow from the words "so that," leading from the first clause ("propriety is altogether a matter of how actions appear") to the second clause. Only (B) is an acceptable answer. It follows from the author's distinction between propriety and morality because it states that hypocrisy (associated with the concept of morality) does not apply to the question of propriety. This question is difficult.

6. (A) obscenity (B) hypocrisy (C) oppression (D) good art (E) decorum

The answer to this very difficult question must meet two requirements. It must describe something that is consistent, in the context of the author's discussion, with the reading of pornography. It must also explain the paradox, described in the preceding lines, of a society in which pornography is read although public sale of pornography is forbidden. The sense of the author's argument is that it is possible not to call such a society hypocritical (lines 4—8). Therefore (B) is a poor choice. (A), "obscenity," is a term similar to "pornography" and does not suggest any contrast that could explain the paradox. "Oppression" and "good art," though relevant in general to the topic of pornography, are not relevant to the author's discussion here. Thus (C) and (D) can be eliminated. (E), "decorum," a synonym of "propriety" does fit into the context. It explains the contrast between privately reading pornography and publicly banning it, according to the author's view that propriety has to do with public appearance only and not with private actions. Thus (E) is the correct answer.

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ANALYSIS OF EXPLANATIONS

Directions: For each set of questions, a fact situation and a result are presented. Several numbered statements follow the result. Each statement is to be evaluated in relation to the fact situation and result.

Consider each statement separately from the other statements. For each one, examine the following sequence of decisions, in the order A, B, C, D, E. Each decision results in selecting or eliminating a choice. *The first choice that cannot be eliminated is the correct answer.*

A Is the statement *inconsistent* with, or contradictory to, something in the fact situation, the result, or both together?
If so, choose A.
If not,

B Does the statement present a *possible adequate explanation* of the result?
If so, choose B.
If not,

C Does the statement have to be true if the fact situation and result are as stated?
If so, the statement is *deducible* from something in the fact situation, the result, or both together; choose C.
If not,

D Does the statement either support or weaken a possible explanation of the result?
If so, the statement is *relevant* to an explanation; choose D.

E If not, the statement is *irrelevant* to an explanation of the result; choose E.

Use common sense to decide whether explanations are adequate and whether statements are inconsistent or deducible. No formal system of logic is presupposed. Do not consider extremely unlikely or remote possibilities.

Sample Set

Situation: In an attempt to end the theft of books from Parkman University Library, Linora Johnson, the chief librarian, initiated a stringent inspection program at the beginning of the fall term. At the library entrance, Johnson posted inspectors to check that each library book leaving the building had a checkout slip bearing the call number of the book, its due date, and the borrower's identification number. The library retained a carbon copy of this slip as its only record that the book had been checked out. Johnson ordered the inspectors to search for concealed library books in attaché cases, bookbags, and all other containers large enough to hold a book. Since no new personnel could be hired, all library personnel took turns serving as inspectors, though many complained of their embarrassment in conducting the searches.

Result: During that term Margaret Zimmer stole twenty-five library books.

29. Zimmer stole the books before the inspection system began.

The answer to this question of average difficulty is A, because the statement is inconsistent with the information given in the result, which states that Zimmer stole the books during the term in which the inspection system was initiated.

30. Zimmer dropped the books out of a second-story window into a clump of bushes and retrieved them after she left the building.

Since the statement could be true given the information in the situation and the result, this statement is consistent with the information given, so the correct answer is not A. The next option to be considered is B. The statement is a possible explanation of the result, since Zimmer could have avoided the inspection system in this way. This question is an easy one.

31. During that term, if Zimmer carried a bookbag out of the library entrance door during regular hours, an inspector was supposed to check it.

This statement is not inconsistent with the information given, so the correct answer cannot be A. Although the statement brings to mind two possible explanations of the result (that Zimmer removed the books after regular hours, or that a negligent inspector failed to check her bag), it does not actually state either of these possibilities. Therefore, the correct answer cannot be B. At this point, in fact, one might be tempted to conclude that the statement weakens a possible explanation of the result (an explanation stating that Zimmer stole the books by hiding them in her bookbag) and might therefore decide that D is the correct answer. However, according to the directions, the next option to be considered is C. The statement can be deduced from the information given, since it is stated that inspectors had been ordered to search for concealed library books in bookbags. The correct answer to this question is therefore C.

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32. The library had at one time kept two carbon copies of each checkout slip.

This statement is not inconsistent with the information given, is not a possible explanation of the result, cannot be deduced from the information given, and does not support or weaken a possible explanation of the result. Information about the system used in the past is not relevant to any explanation of the result, so the correct answer is E.

33. The doors to the library fire escapes are equipped with alarm bells set off by opening the doors.

This statement is not inconsistent with the information given, and it is not a possible explanation of the result. It cannot be deduced since it is not necessarily true given the information in the situation and the result. The correct answer is D because the statement *weakens* a possible explanation of the result. For instance, an explanation stating that Zimmer dropped the books from a fire escape to a confederate below would be unlikely if it were known that the fire escape doors could not be opened without setting off an alarm.

LOGICAL DIAGRAMS

Directions: **In this part, you are to choose from five diagrams the one that illustrates the relationship among three given classes better than any of the other diagrams offered.**

There are three possible relationships between any *two* different classes:

indicates that one class is completely contained in the other, but not vice versa.

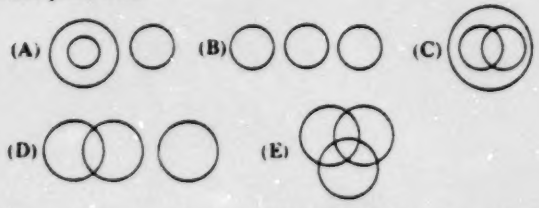
indicates that neither class is completely contained in the other, but the two do have members in common.

indicates that there are no members in common.

Note: **The size of the circles does *not* indicate relative size of the classes.**

Example:

Birds, pets, trees



The correct answer, (D), shows that one of the classes (trees) has no members in common with the other two. (No trees are either birds or pets, and no birds or pets are trees). (D) also shows that the other two classes have some members in common, but neither is completely included in the other (some birds are pets and some pets are birds, but there are birds that are not pets and there are pets that are not birds).

The five possible choices for all the problems in this part are given at the top of the next column.

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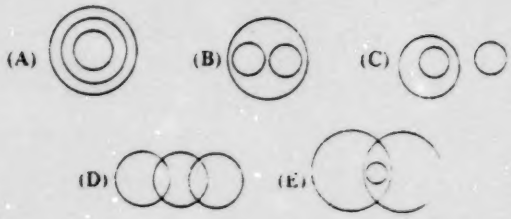

34. Nuts, pecans, forks

One of the classes (pecans) is completely contained in another (nuts). That is, all pecans are nuts, but the category nuts includes other kinds of nuts as well as pecans. The third class (forks) has no members in common with either of the other two classes. Therefore the correct answer is (C).

35. Adult women, infants, black-haired people

Since two of the classes (adult women and infants) have no members in common, the correct answer must include two circles that do not overlap. Black-haired people may be adult women, and adult women may be black-haired people, but neither class is completely contained in the other. The same is true of the relationships between infants and black-haired people. The correct answer is therefore (D), which shows that, while two of the classes have no members in common, each of them has some members in common with the third class.

36. Fish, minnows, things that live in water

ANALYTICAL REASONING

Directions: **Each question or group of questions is based on a passage or set of statements. In answering some of the questions it may be useful to draw a rough diagram. Choose the best answer for each question and blacken the corresponding space on your answer sheet.**

Questions 37–38

(1) It is assumed that a half tone is the smallest possible interval between notes.
(2) Note T is a half tone higher than note V.
(3) Note V is a whole tone higher than note W.
(4) Note W is a half tone lower than note X.
(5) Note X is a whole tone lower than note T.
(6) Note Y is a whole tone lower than note W.

37. Which of the following represents the relative order of the notes from the lowest to the highest?

(A) X Y W V T (B) Y W X V T (C) W V T Y X
(D) Y W V T X (E) Y X W V T

The answer to this relatively easy question can be determined by reading the six given statements and understanding the relationships among them. The relationships may be clarified by drawing a simple illustrative diagram:

T
V
X
W

Y

The diagram shows the relative order of the notes; since the question asks for the order from the lowest note to the highest, the correct answer is (B).

38. Which of the following statements about an additional note, Z, could NOT be true?

(A) Z is higher than T. (B) Z is lower than Y.
(C) Z is lower than W. (D) Z is between W and Y.
(E) Z is between W and X.

Since W and X are a half tone apart (statement 4), and since a half tone is assumed to be the smallest possible interval between notes (statement 1), Z cannot be between W and X. The correct answer is therefore (E). The question can also be answered by referring to the diagram.

Questions 39–40

(1) A red ticket is required for entrance.
(2) You can get a red ticket if you have your blue form signed by the director.
(3) The director will only sign the blue form if you surrender your yellow pass to him.
(4) If you have a green slip, you can exchange it for a yellow pass, but only if the director has signed your blue form.
(5) If you have a valid driver's license, you do not have to have your blue form signed by the director in order to get a red ticket.
(6) You can get a yellow pass on request, but only if you do not already have a green slip.

39. The above procedures fail to specify

(A) whether anything besides a red ticket is required for entrance
(B) whether you can exchange a green slip for a yellow pass
(C) the condition under which the director will sign the blue form
(D) how to get a red ticket if you have a yellow pass
(E) how to bypass the requirement of having the blue form signed

To answer this question, it is necessary to determine what information is NOT given. The information in options (B), (C), and (E) is given in statements 4, 3, and 5, respectively. The information in (D) is provided by statements 3 and 2 taken together. The correct answer is therefore (A).

40. Having which of the following makes it impossible for someone without a driver's license to enter?

(A) A signed blue form (B) An unsigned blue form
(C) A yellow pass (D) A red ticket (E) A green slip

Answering this relatively difficult question requires combining information from several of the given statements. In order to enter, a red ticket is required (statement 1). In order to get a red ticket, a person who does not have a driver's license must have a blue form signed by the director (statement 5). The director will sign the blue form only for someone who has a yellow pass (statement 3). A person who has a green slip cannot get a yellow pass (statement 2). The correct answer is therefore (E). Having a green slip makes it impossible for a person without a driver's license to enter.

ANSWER KEY

Verbal			Quantitative			
1. A	5. A	9. D	13. C	17. [illegible]	21. C	25. A
2. E	6. C	10. B	14. E	18. D	22. A	26. D
3. C	7. D	11. D	15. C	19. [illegible]	23. C	27. B
4. B	8. C	12. B	16. B	20. [illegible]	24. B	28. C

Analytical		
29. A	33. D	37. B
30. B	34. C	38. E
31. C	35. D	39. A
32. E	36. A	40. E

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Appendix B

Factor Analyses of Operational Forms:

Orthogonal Solution

Table B.1

Distribution of Varimax Loadings by Item Type (Form A)

Factor	Item Type	Number of Items	Number of Loadings greater than: .20	.40	.60	Number of Items having Highest Loading on this Factor	Highest Loadings on this Factor from	Comments
I	Verbal:	95	83	40	6	56	Reading passages.	Best defined by reading passage items.
	Analogies	17	15	6	0	8		
	Opposites	20	10	5	1	5		
	Sent. Comp.	18	18	9	2	7		
	Reading Passages	40	40	25	3	36		
	Quant.	55	23	2	0	3		
II	Verbal	95	18	2	0	2	Quantitative items.	Two verbal items having their highest loadings are from a biology passage. Very high loadings at end of quant. section.
	Quant.	55	55	42	17	46		
III	Verbal:	95	46	24	6	26	Opposites.	Best defined by difficult opposites
	Analogies	17	14	7	2	9		
	Opposites	20	17	13	4	13		
	Sent. Comp.	18	11	4	0	3		
	Reading Passages	40	4	0	0	0		
	Quant.	55	0	0	0	0		
IV	Verbal	95	1	0	0	0	Quantitative items.	Best defined by relatively easy items requiring algebraic manipulation.
	Quant.	55	25	7	1	6		
V	Verbal:	95	14	5	1	8	Sentence completion.	Defined by high loadings on last items in Section I.
	Sent. Comp.	18	9	8	1	8		
VI	Verbal:	95	9	3	0	3	Reading passages.	Defined by high loadings from the last items in Section II.
	Reading Passages	40	9	3	0	3		
	Quant.	55	2	0	0	0		
VII	Verbal	95	3	0	0	0	Data interpretation.	Defined by data interpretation items.
	Quant.:	55	6	0	0	0		
	Data Interp.	15	6	0	0	0		
VIII	Verbal:	95	6	0	0	0	Reading passages.	Characterized by modest loadings from the first reading passage.
	Reading Passages	40	6	0	0	0		
	Quant.	55	0	0	0	0		

Table B.2

Distribution of Varimax Loadings by Item Type (Form B)

Factor	Item Type	Number of Items	Number of Loadings greater than: .20	.40	.60	Number of Items having Highest Loading on this Factor	Highest Loadings on this Factor from	Comments
I	Verbal	100	20	1	0	1	Quantitative items.	Best defined by final quantitative items.
	Quant.	55	55	42	17	48		
II	Verbal:	100	84	35	4	54	Reading passages.	Best defined by reading passages.
	Analogies	20	15	6	0	7		
	Opposites	20	11	7	0	7		
	Sent. Comp.	20	19	8	0	9		
	Reading Passages	40	39	14	4	31		
	Quant.	55	22	0	0	0		
III	Verbal:	100	55	25	2	26	Opposites and analogies.	Best defined by opposites and analogies.
	Analogies	20	17	11	1	13		
	Opposites	20	15	9	1	11		
	Sent. Comp.	20	13	5	0	0		
	Reading Passages	20	10	0	0	2		
	Quant.	55	0	0	0	0		
IV	Verbal:	100	13	11	6	10	Sentence completions.	Very high loadings from last items in Section I.
	Sent. Comp.	20	10	10	6	10		
	Opposites	20	3	1	0	0		
V	Verbal	100	1	0	0	0	Quantitative items.	Defined best by one unusual data interpretation set involving manipulation of tabled entries.
	Quant.:	55	7	4	4	4		
	Data Interp.	16	6	4	4	4		
VI	Verbal:	150	7	5	0	7	Reading passages.	Defined by high loadings from reading passage at end of Section II.
	Reading Passages	40	7	5	0	7		
VII	Quant.:	55	10	6	0	2	Data interpretation.	Defined by data interpretation items involving primarily extraction of information.
	Data Interp.	16	8	6	0	2		
VIII	Verbal:	100	11	0	0	2	Opposites.	Defined by easy opposites items.
	Opposites	20	8	0	0	2		

Table B.3

Summary of Item Types in Operational Forms

Section	Item Description		Item Number		Time Limit
	Form A	Form B	Form A	Form B	in Minutes
I	Discrete verbal:	Discrete verbal:	1-55	1-60	25
	Analogies	Analogies	1-9	1-10	
	Opposites	Opposites	10-19	11-20	
	Sentence Completions	Sentence Completions	20-28	21-30	
	Analogies	Analogies	29-36	31-40	
	Opposites	Opposites	37-46	41-50	
	Sentence Completions	Sentence Completions	47-55	51-60	
II	Reading Comprehension:	Reading Comprehension:	1-40	1-40	50
	Narrative passage	Argumentative passage	1-7	1-7	
	Biological scientific passage	Physical science passage	8-13	8-13	
	Argumentative passage	Humanities passage	14-20	14-20	
	Humanities passage	Social studies passage	21-27	21-27	
	Social studies passage	Narrative passage	28-33	28-33	
	Physical science passage	Biological science passage	34-40	34-40	
III	Quantitative:	Quantitative:	1-55	1-55	75
	Algebra, arithmetic, geometry, and miscellaneous	Algebra, arithmetic, geometry, miscellaneous	1-5	1-7	
	Data interpretation	Algebraic table	6-11	8-12	
	Algebra, arithmetic, geometry, miscellaneous	Algebra, arithmetic, geometry, miscellaneous	12-25	13-23	
	Data interpretation	Data interpretation	26-30	24-28	
	Algebra, arithmetic, geometry, miscellaneous	Algebra, arithmetic, geometry, miscellaneous	31-44	29-39	
	Data interpretation	Data interpretation	45-48	40-45	
	Algebra, arithmetic, geometry, miscellaneous	Algebra, arithmetic, geometry, miscellaneous	49-55	46-55	

Appendix C

Factor Extension Loadings for Experimental Tests

Table C.1

Factor Extension Loadings of Test X_{21} (Letter Sets) on Operational Form A Factors (Varimax Solution)

	I	II	III	IV	V	VI	VII	VIII
1	34	25						
2	21							
3	21	22		37				
4	39			[illegible]				
5	39	28						
6	39	30		32				
7	30	28	28	28				
8	35			32				
9	22	21						
10	37	25		36				
11	29	28		27				
12	33	24		39				
13	31	21		28				
14	29	21		21				
15	43	28		25				
16	42	27		39				
17	46	22		37				
18	38			31				
19	37	35		28				
20	35	26		31				
21	29	25		29				21
22	36	28		31				
23	45	30		33		20		
24	38	31		35		20		
25	36	38		31				
26	33	33		23				20
27	32	34		37		27		
28	32	32		29		22		
29	35	37		34	22	35		
30	33	42		30	22	25		
31	36	43		33	22	28		
32	32	45		26		29		
33	25	41		32		21		
34	26	42		24		20		21
35	28	46		31	23	24		
36	27	45		32	21			
37	25	43		24	23			
38	24	46		27	21			
39	26	43		22	27			
40	22	43		26	26			

Table C.2

Factor Extension Loadings of Test X_{22} (Logical Reasoning/Letter Sets) on Operational Form A Factors (Varimax Solution)

		I	II	III	IV	V	VI	VII	VIII
Logical Reasoning	1	45	21						
	2	40	20						
	3	45	27						
	4	20							
	5	34	33						
	6	37	20						
	7	49	23						
	8	25							
	9	28	26						
	10	30							
	11	24		21					
	12	37	29						20
	13	44	24	23					
	14		27	25					
	15	22	20						
Letter Sets	16	27			23				22
	17	33	29		25		25		
	18	25	31		25		20		
	19	27	27		24		31		22
	20	31	24		20	33	34		
	21	24	28			26	35		
	22	25	34			32	29		
	23	22	26			22	31		
	24	25	34		21	32	31		21
	25	21	33		21	24	28		
	26		34		22	28	30		
	27		36		21	28	31		
	28	20	37			29	27		22
	29		38			25	25		23
	30		36			29	21		21

Table C.3

Factor Extension Loadings of Test X_{23} (Letter Sets/Analytical Reasoning) on Operational Form A Factors (Varimax Solution)

		I	II	III	IV	V	VI	VII	VIII
Letter Sets	1	26							
	2	30			38				
	3	26			31				
	4	23			22				
	5	32			32				
	6	25			27				
	7	25	24		32				
	8	21							
	9	34			39				
	10	26			28				
	11	27	21		29				20
	12	29			31				
	13	25			32				
	14		26						
	15	22			29				
Analytical Reasoning	16	43	39		28				
	17	32	35		25				
	18	47	43		25				
	19	27	45						
	20	34	40		27				
	21	26	42						
	22	20	28				21		25
	23	27	33				20		28
	24	22	26						26
	25	20	35						24
	26	23	24	24					
	27	25	44			22	20		
	28		43			25			
	29	27	38				21		25
	30		49						

Table C.4

Factor Extension Loadings of Test X_{24} (Evaluation of Evidence) on Operational Form A Factors (Varimax Solution)

	I	II	III	IV	V	VI	VII	VIII
1								
2	30	22						
3								
4	50	20						
5	29	21						
6								
7	41			20				
8								
9	25							
10	26	22						
11	29							
12								
13								
14	32							
15								
16	45			23				
17	32							
18							21	
19								
20								
21	35	20						
22	31	20						
23	32					24		
24	28		22					
25	20							
26	26							
27	38							
28	36	20				20		
29	24							
30	38	24						
31	37					22		
32	35				41	39		
33	33	21			24	20		
34	28				36	26		20
35	27				27			
36	27				26	22		
37	27				28	24		
38	28				25	26		
39	36	22			27			
40	27				25			

Table C.5

Factor Extension Loadings of Test X_{25} (Analysis of Explanations) on Operational Form A Factors (Varimax Solution)

	I	II	III	IV	V	VI	VII	VIII
1								
2	25	21						
3	25	21						
4		25						
5								
6	23							
7	25	20						
8	30	39						
9								
10								
11	36	22						
12	31	28						
13	33	23						
14								
15	34							
16								
17								
18	29							
19		20						
20	34	28						
21	41	22						
22	20	20						
23	34							
24	24	21						
25	41	35						
26	29	28						
27	26	20						
28	42			21	20			
29	34	33		23				
30	38	31						
31	28							
32	33	32						
33		24						
34								
35	21	22			20			
36		22						
37	23	32						
38								
39	30	25				21		
40		27						

Table C.6

Factor Extension Loadings of Test Y_1 (Logical Diagrams)

on Operational Form B Factors (Varimax Solution)

	I	II	III	IV	V	VI	VII	VIII
1	45	33						
2	38	35						
3	35	21						
4	44	38						
5	47	31						
6	48	28						
7	33	20						
8	46	29						
9	42	22						
10	43	38						
11	35	43			23			
12	44	35			20			
13	30	24						
14	46	30						
15	48	36						
16	47	42						
17	46	39						
18	43	40						
19								
20								
21	42	41			20			
22		42			30			
23	45	40						
24	30	30						
25								
26	32	24						
27	32	27						
28	35	33						
29	22							
30	42	43			23			
31	30	22				32		
32	34	24				28		
33	38	27						
34	34							
35	34	29						
36	42	29						
37	41	33						
38	35	24						
39	43	29						
40	38	22		20				

Table C.6 (Cont.)

	I	II	III	IV	V	VI	VII	VIII
41	37	23						
42	36				26			
43	41	22						
44	34	22						
45								
46	37	23						
47	39	25				23		
48	33			29		29		
49	28	24				20		
50								

Table C.7

Factor Extension Loadings of Test Y_{10} (Logical Diagrams)

on Operational Form B Factors (Varimax Solution)

	I	II	III	IV	V	VI	VII	VIII
1	29	24			34			
2	29	20			31			
3	32	23			25			
4	33							
5	35	26			32			
6	42	33			30			
7	29							
8	34							
9	37	20						
10	27							
11	23							
12	39							
13	24							
14	39							
15	34					23		
16	31					20		
17	43					27		
18	31					23		
19	35							
20	22				22	22		

Appendix D

Factor Analysis of Operational Forms:

Oblique Solution

Table D.1

Distribution of Factor Pattern Loadings (Oblique Solution, Form A)

Factor	Item Type	Number of Items	Number of Loadings greater than: .20	.40	.60	Number of Items having Highest Loading on this Factor	Highest Loadings on this Factor from	Comments
I	Verbal:	95	33	7	1	23	Reading passage items.	Most clearly defined by reading passage items.
	Analogies	17	7	0	0	2		
	Opposites	20	0	0	0	0		
	Sent. Comp.	18	6	0	0	3		
	Reading Passages	40	20	7	1	18		
	Quant.	55	0	0	0	0		
II	Verbal	95	3	0	0	1	Difficult quantitative items.	General quantitative defined most clearly by difficult items.
	Quant.	55	37	20	7	26		
III	Verbal	95	28	18	3	23	Opposites.	Best defined by loadings from difficult opposite items and to a somewhat lesser extent by difficult analogies.
	Analogies	17	11	4	0	10		
	Opposites	20	13	12	3	13		
	Sent. Comp.	18	4	2	0	0		
	Reading Passages	40	0	0	0	0		
	Quant.	55	0	0	0	0		
IV	Verbal	95	2	0	0	1	Easy quantitative items.	
	Quant.	55	30	13	3	25		
V	Verbal:	95	15	9	5	14	Sentence completion.	Best defined by very high loadings from final items in Section I.
	Sent. Comp.	18	11	9	5	9		
VI	Verbal:	95	0	0	0	0	Reading passages.	High loadings from final items in Section II.
	Reading Passages	40	17	7	0	13		
	Quant.	55	1	0	0	0		
VII	Verbal	55	9	0	0	4	Data interpretation.	Best defined by high loadings from a data interp. set dealing with spatial relations.
	Quant.:	95	11	0	0	4		
	Data Interp.	15	7	0	0	4		
VIII	Verbal:	95	19	0	0	10	Reading passages.	Best defined by loadings from a specific reading passages.
	Reading passages	40	9	0	0	7		
	Quant.	55	1	0	0	0		

Table D.2

Distribution of Factor Pattern Loadings (Oblique Solution, Form B)

Factor	Item Type	Number of Items	Number of Loadings greater than: .20	.40	.60	Number of Items having Highest Loading on this Factor	Highest Loadings on this Factor from	Comments
I	Verbal	100	1	0	0	1	Quantitative items.	Best defined by a majority of quantitative items.
	Quant.	55	37	27	8	33		
II	Verbal:	100	1	0	0	1	Reading passages.	Especially high loading from one passage.
	Analogies	20	10	0	0	0		
	Opposites	20	6	1	0	2		
	Sent. Comp.	20	8	0	0	9		
	Reading Passages	40	25	8	3	25		
	Quant.	55	0	0	0	0		
III	Verbal:	100	40	16	1	33	Opposites.	Defined best by difficult opposites and difficult analogies.
	Analogies	20	17	7	0	18		
	Opposites	20	14	9	1	12		
	Sent. Comp.	20	6	0	0	1		
	Reading Passages	40	3	0	0	2		
	Quant.	55	0	0	0	0		
IV	Verbal:	100	15	10	9	10	Sentence completion.	Best defined by very high loadings from final items in Section I.
	Sent. Comp.	20	10	10	9	10		
	Opposites	20	5	0	0	0		
V	Quant.:	55	15	4	4	7	One set requiring use of an algebraic table.	Best defined by very high loadings from the algebraic items set and one high loading from another data interp. item.
	Data Interp.	16	6	4	4	5		
VI	Verbal:	100	16	6	3	11	Reading passages.	Defined by final items in Section II.
	Reading Passages	40	12	6	3	11		
VII	Quant.:	55	15	8	4	14	Data Interp.	Best defined by items in one data interp. set.
	Data Interp.	16	9	6	4	9		
VIII	Verbal:	100	12	2	1	6	Opposites.	Best defined by high loadings from easy opposites items.
	Opposites	20	9	2	1	6		